New Scientist

WEEKLY 2 May 2020

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Why a vaccine is still a long way off

The deadly coronaviruses we've now learned to live with

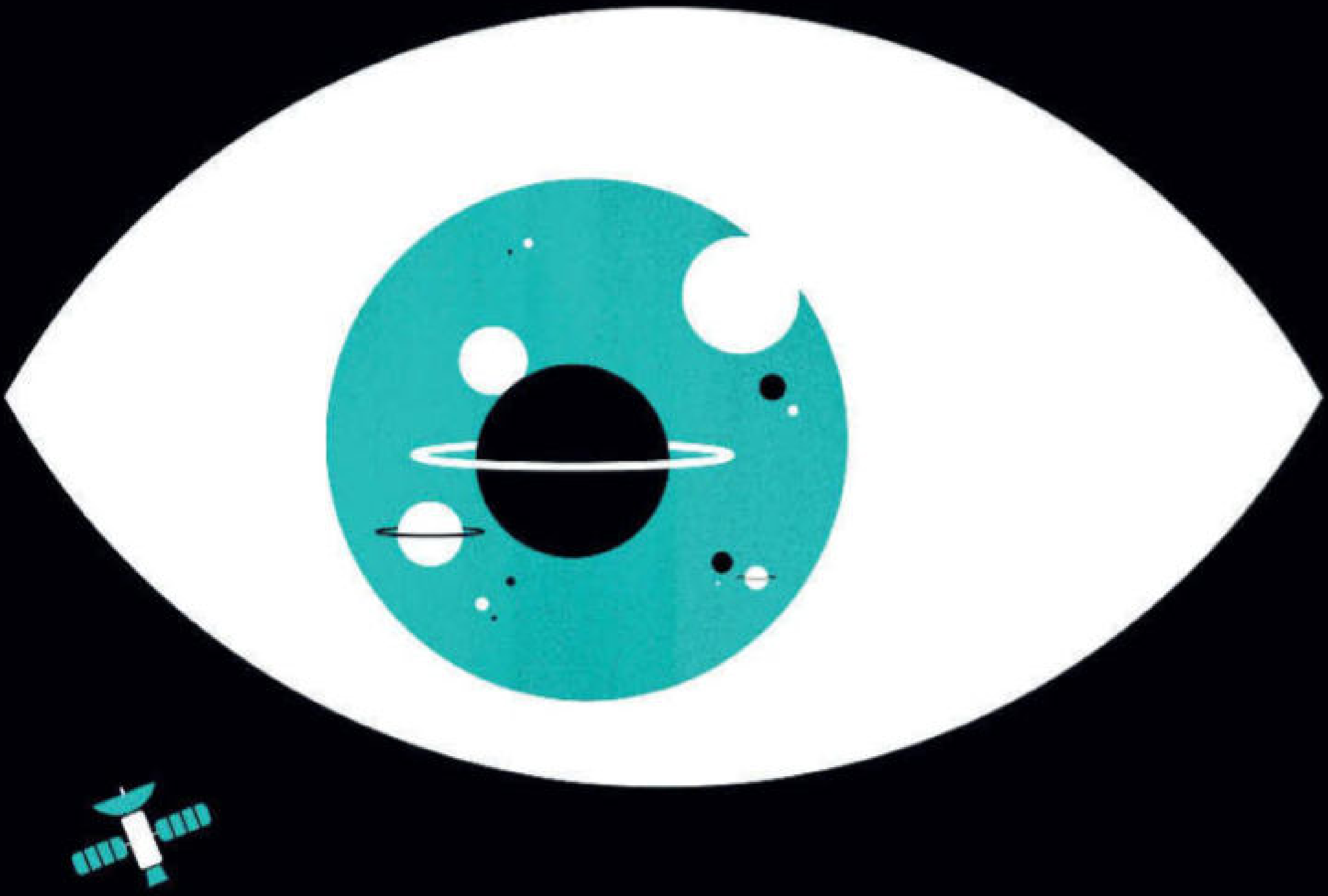
Understanding death data

Caution over antibody tests

Interview with a contact tracer

IS THE UNIVERSE CONSCIOUS?

It sounds implausible. But that's until you do the maths



HOW THE TURTLE GOT ITS SHELL

Evolutionary puzzle finally cracked

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We’re looking for the best ideas in the world.

The Ryman Prize is an international award aimed at encouraging the best and brightest thinkers in the world to focus on ways to improve the health of older people.

The world’s ageing population means that in some parts of the globe – including much of the Western world – the population aged 75+ is set to almost triple in the next 30 years.

The burden of chronic diseases including Alzheimers and diabetes is set to grow at the same time.

In order to stimulate fresh efforts to tackle the problems of old age, we’re offering a $250,000 annual prize for the world’s best discovery, development, advance or achievement that enhances quality of life for older people.

The Ryman Prize was first awarded in 2015 to Gabi Hollows, co-founder of the Hollows Foundation, for her tireless work to restore sight for millions of older people in the developing world.

World-leading researchers Professor Henry Brodaty and Professor Peter St George-Hyslop won the prize in 2016 and 2017 respectively for their pioneering work into Alzheimer’s Disease.

The 2018 Ryman Prize went to inventor Professor Takanori Shibata for his 25 years of research into robotics and artificial intelligence.

The 2019 prize winner was Dr Michael Fehlings, a Canadian neurosurgeon who has dedicated a long career to helping older people suffering from debilitating spinal problems.

If you have a great idea or have achieved something remarkable like Gabi, Henry, Peter, Takanori or Michael we would love to hear from you.

Entries for the 2020 Ryman Prize close at 5pm on Friday, June 26, 2020 (New Zealand time).

Go to www.rymanprize.com for more information

Prime Minister Jacinda Ardern with 2019 Ryman Prize winner Dr Michael Fehlings.

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Matter over mind

A fresh approach may help us see consciousness in a new way

LIFE at the moment seems full of questions where everyone has an opinion, but few can supply a convincing answer. By way of diversion, let us instead consider a question that invites few coherent opinions, but screams what seems to be a correct answer.

Ask "is the universe conscious?", as we do on this week's cover, and the brain-jerk answer is "no". Consciousness is a case of the haves and have nots. Humans clearly have it; a rock, a star or other agglomeration of physical matter, such as the wider cosmos, doesn't. The venerable philosophical idea of universal sentience, or "panpsychism", says otherwise when it comes to inanimate things, but it seems to have no more place in modern science than a belief in fairies at the end of the garden.

However, an enquiring mind does well to leave its intuitions at the door. How certain arrangements of matter such as the neuronal circuits in our brains give rise to felt experience, while others don't, is a "hard problem". It is difficult to set boundaries on consciousness when we don't really know what it is. Does an octopus have it? A tree? A bacterium? A sentient robot?

Propose that all matter has consciousness in some form, differing only in degree, and you go some way to setting aside such basic problems. That still isn't an argument. But the realisation that our mathematically most mature theory of consciousness, integrated information theory, gives succour to panpsychism, could well be (see page 40).

> **"Mathematics has an extraordinary way of leading us to enlightenment by subverting our intuitions"**

Mathematics has, in physicist Eugene Wigner's phrase, shown an "unreasonable effectiveness" in tackling hard problems of science, and has been an extraordinary way of leading us to enlightenment by subverting intuitions. Just ask any student of quantum theory or relativity where those theories lie in relation to the grain of our brains.

Of course, there are more things on heaven and Earth than are dreamed of even in mathematical philosophy. It may be that, as a tool developed by consciousness, mathematics reaches a limit in describing the phenomenon itself. Who knows – but what a delightful distraction it is to consider such esoteric questions at a time like this. ∎

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Death counts may far exceed official numbers **p7**

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RICHARD POHLE/THE TIMES/PA WIRE

Political adviser Dominic Cummings has attended UK scientific meetings

UK advisers to be named

Criticism of the UK's Scientific Advisory Group for Emergencies has prompted a move to more transparency, reports **Adam Vaughan**

A LIST of people who have been giving scientific advice to the UK government during the coronavirus pandemic is set to be published imminently, following concerns over transparency.

The membership of the UK's Scientific Advisory Group for Emergencies (SAGE) and the minutes of its meetings are normally only published after a crisis has passed, but this approach has been criticised.

Last week, *The New York Times* described SAGE as a "virtual black box", while *The Guardian* revealed that meetings had been attended by prime minister Boris Johnson's divisive top political adviser, Dominic Cummings. UK chief scientific adviser Patrick Vallance has now said details of the group's workings will be published sooner.

"I think we should publish names soon, and we will do so shortly," he told journalists on Monday. Names were kept secret for various reasons, including security, he said, and more than a hundred are likely to be on the list of those happy to be named.

A list obtained by *The Guardian* revealed that SAGE meetings had been attended by Cummings and Ben Warner, a Downing Street official who previously worked on the computer model used by the pro-Brexit Vote Leave campaign in 2016. The government hasn't denied that the two were present in February and March, but has said they only attended the meetings and aren't on SAGE.

Vallance downplayed the significance of their presence. He said officials could ask questions, but weren't part of the "general discussion". Political advisers have attended SAGE meetings during past crises, he said.

"All I'm worried about is the prime minister hears SAGE advice from me. I can't tell who else he's hearing scientific advice from," he said.

Vallance also discussed the publication of minutes from SAGE meetings, which he has previously said won't happen until after the crisis. "I think minutes coming out immediately after the meeting is not sensible, they need to go through the political process and minutes will be published in the usual way." But the covid-19 crisis is unique, as it isn't clear when it will end, he said.

The only work made public by SAGE so far is some of the research it has discussed, published on 20 March. That hasn't been updated in more than a month, though *New Scientist* understands it will be refreshed in coming days.

"I think any steps to make the SAGE process more transparent are very welcome, if overdue, given that many have been calling for this now for weeks," says James Wilsdon at the University of Sheffield, UK.

Helen Ward at Imperial College London welcomes the fact that names will be published, but says revealing the nature of SAGE's discussions is also key.

"It's always good to be more transparent than SAGE have been. But without seeing the details of any minutes, it's still difficult to know [how decisions are being reached]," she says. More transparency is also needed on the political decision-making process that SAGE informs, she says, such as why contact tracing was dropped two months ago.

Minutes from SAGE would provide a vital timeline and help outsiders determine why some of the UK's controversial strategies for managing the crisis were chosen at particular times, says Anthony Costello at University College London. "It's important that we can see the advice at different critical stages." ▮

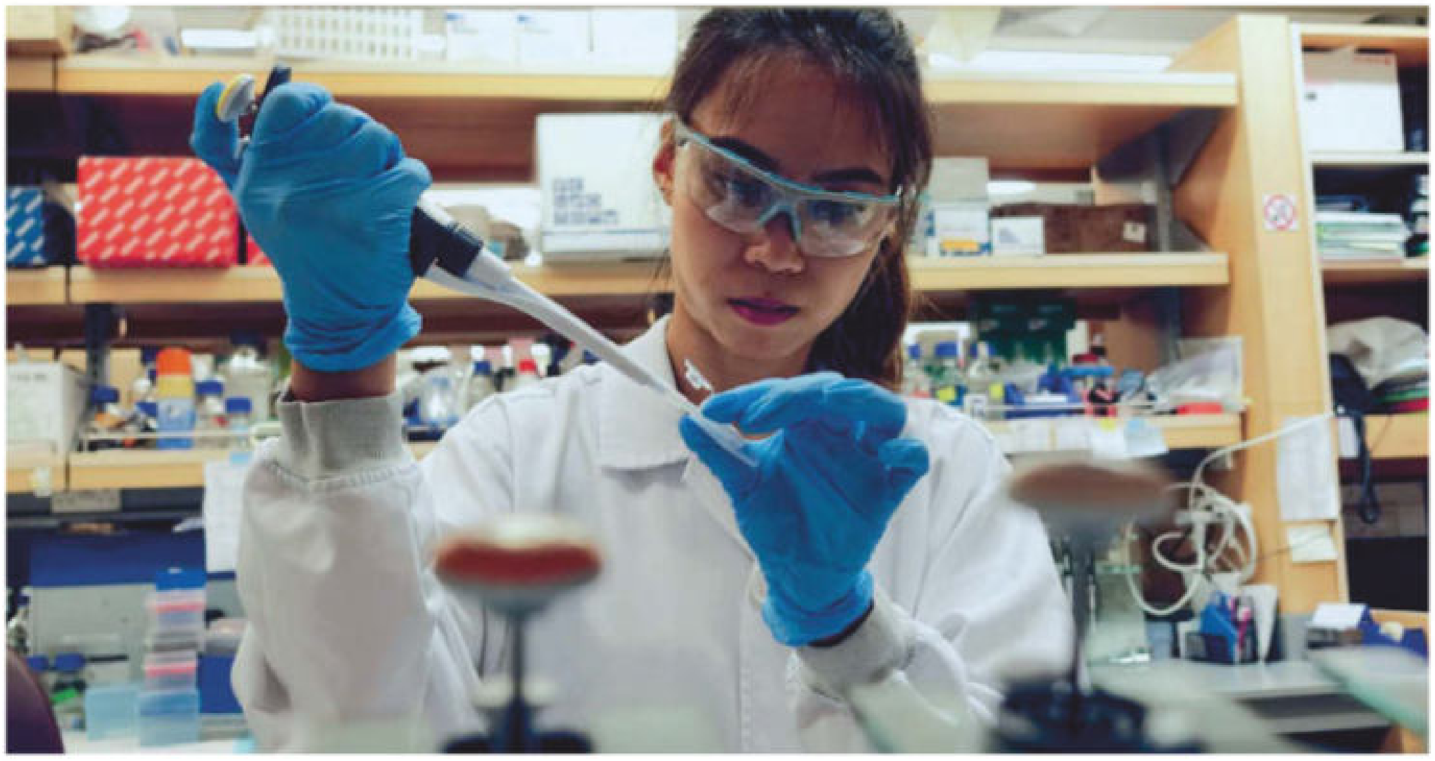
Daily round-up of global coronavirus news
Updated online every weekday
newscientist.com/coronavirus-latest

Analysis **Clinical trials**

A vaccine is still a long way off

Trials are under way but we can't count on a vaccine to get us out of the crisis

Carrie Arnold



REUTERS/JOSEPH CAMPBELL

A lab in Singapore is one of many working on coronavirus vaccines

MANY UK newspapers recently celebrated the first volunteer to receive an injection as part of a safety trial of an experimental coronavirus vaccine. But while there are claims that it could be possible for a vaccine to be ready within a year, the chances of this happening remain slim.

The UK trial, led by the University of Oxford, will ultimately involve 1100 adults, half of whom will receive the experimental vaccine. The other half will get a meningitis vaccine as a control. The team behind the trial hopes to move on to tests to gauge how effective the vaccine is against the coronavirus as early as August, raising hopes that a vaccine could be ready before the end of the year, and that this could be the answer to the difficult question of how the country gets out of strict social distancing measures.

Unfortunately, these hopes are probably misplaced. Vaccine design expert Maria Bottazzi of Baylor College of Medicine in Houston, Texas, calls the schedule "unrealistic". Even if everything goes according to plan in the first phase of trials, Bottazzi points out that researchers will still need time to determine how well the vaccine protects people from covid-19 and whether it provokes any side effects when a vaccinated person is subsequently exposed to the virus.

It is far from guaranteed that the vaccine will be safe and effective. A 2013 study calculated that, before entering clinical trials, the average experimental vaccine has a 6 per cent chance of ultimately reaching the market. Of those that make it into trials, a 2019 analysis suggests the probability of success is 33.4 per cent.

But even if the Oxford vaccine succeeds, there will then be the issue of scaling up manufacturing to make hundreds of millions of doses. According to Bottazzi, this is the real bottleneck. Under the best of circumstances, the world is still looking at 12 to 18 months before a vaccine could be widely available, she says.

That in itself would be a remarkable achievement. The 2013 study found that between 1998 and 2009, the average time taken to develop a vaccine was 10.7 years. It is possible to speed this up to some extent – since then, an Ebola vaccine has become the fastest-developed vaccine ever, being produced in just five years.

But to lower this to just 18 months would require the next steps of the development process to be begun before the previous ones were completed, Bottazzi says. This increases the risk of significant loss of investment should the vaccine fail to pan out, as well as raising questions about safety. An expedited path from early trials to scaled-up manufacturing would mean that researchers won't have as much time to study the long-term effects of a vaccine in trial participants before it is given to the public, for example.

> **"Between 1998 and 2009, the average time taken to develop a vaccine was 10.7 years"**

To try to speed things up, on 21 April, UK health minister Matt Hancock said that the government will put money into manufacturing capability, in the hope that either the Oxford vaccine, or another vaccine being tested by Imperial College London, will prove successful. Similar measures are being taken elsewhere. US philanthropist Bill Gates has announced he is helping to build manufacturing capability for seven candidate vaccines – a strategy he said will lose billions of dollars but save time.

More than 100 vaccines for the coronavirus are currently in various early stages of development. The more that are tested, the higher the chances of finding something that is both safe and effective.

Yet there is no guarantee that it is even possible to vaccinate against the coronavirus. There is a lot we don't know yet about how our immune systems respond to the virus, and whether it is possible to induce long-lasting immunity to it.

Hancock also said that the government is "throwing everything" at developing a coronavirus vaccine. But given the time it will take to get one – if it even proves possible to do so – it is clear that countries can't wait for a vaccine to get them out of their current crises. As epidemiologist Mark Woolhouse at the University of Edinburgh, UK, told *New Scientist* in early April: "I do not think waiting for a vaccine should be dignified with the word 'strategy'. It's not a strategy, it's a hope."

We need to be realistic about the hopes of a vaccine, but that doesn't mean it isn't worth trying. Like annual flu vaccines, an effective coronavirus vaccine could help us protect those most at risk from the virus. As with childhood vaccines for measles and other diseases, it may also enable us to protect future generations from covid-19.

But it could be years before we have a vaccine. Until then, we will need to deal with multiple waves of infection with measures such as extensive testing, contact tracing and quarantining. ▮

Briefing

How many people have died?

Excess death counts give a more accurate idea of the coronavirus's true impact, reports **Michael Le Page**

WITH few countries doing enough testing to identify anywhere near all the deaths caused by the coronavirus, looking at how many more people are dying than usual is a better way of assessing the pandemic's effect.

Why are the covid-19 death counts underestimates?

Reported coronavirus deaths are typically severely ill people who have tested positive for the coronavirus in a hospital. However, many people who have died may not have been tested – especially those who died at home or in a care home. Looking at the number of excess deaths suggests the true death toll has been higher than the number reported in many places, including Italy, Spain, Sweden, and England and Wales.

What are "excess deaths"?

It is how many more people are dying than would be expected. For instance, at this time of year, normally around 50,000 people die each week in the 24 European countries that report deaths to the EuroMOMO monitoring scheme. This has shot up to about 90,000, according to the latest numbers, which aren't yet complete.

How big is the disparity with official counts?

It varies. One study estimates that the coronavirus had caused the deaths of 52,000 people in Italy by 18 April (medRxiv, doi.org/ds6s) – more than double the reported figure. Similarly, a *Financial Times* analysis suggests the virus had led to 45,000 deaths in the UK by 21 April, more than twice the official figure then of 17,000.

Are all the excess deaths due to the coronavirus?

Figures from the UK's Office for National Statistics indicate that the coronavirus is to blame for more than two-thirds of the excess deaths in England and Wales, based on the number of confirmed or suspected cases of covid-19 reported on death certificates.

45,000

UK death toll for 21 April estimated from excess deaths

That leaves roughly a third of excess deaths unexplained. Some of these may have been coronavirus cases without obvious symptoms, or cases where doctors weren't confident enough to mention covid-19 on the death certificate. However, some of the unexplained excess deaths could be a result of more people dying of other causes, such as heart attack or stroke, because some are avoiding going to hospital due to the coronavirus. Emergency admissions figures from Public Health England suggest that attendance at hospital emergency departments in England was down about 50 per cent in April.

What about the crisis's impact on hospitals?

It is certainly possible that some of the unexplained deaths may be indirect coronavirus deaths: people receiving less than the usual standard of medical care for a non-coronavirus condition due to the strain the virus is placing on healthcare systems.

Will we ever know the true toll of the virus?

Not exactly. But we will be able to get a much clearer picture once the crisis eventually ends and the overall number of deaths in 2020 and 2021 can be compared with other years.

What we do know for now is that most countries' death tolls are undoubtedly underestimates – and for places including the US and Europe, many more deaths are still expected. ▮

MICHAEL DANTAS/AFP VIA GETTY IMAGES

A burial takes place at a site in Manaus, Brazil, in graves dug due to the covid-19 pandemic

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Testing

Monitor sewage to track spread of the coronavirus

Colin Barras

WE COULD begin monitoring about 2 billion people for coronavirus infection simply by looking at waste water.

"It feels like a no-brainer: everything is in place to do this," says Rolf Halden at Arizona State University.

Such monitoring would be a fraction of the cost of traditional clinical testing and could be done using essentially the same methods now being used to test individuals.

Depending on local factors, including the temperature of the waste water and the size of the sewerage system, Halden and his colleague Olga Hart say it should be possible to detect coronavirus in sewage if just one in every 114 of the people using the sewerage system is infected.

In ideal situations where, for instance, the waste water is cool enough to preserve viral RNA, Halden and Hart estimate that waste water testing could detect the virus even if just one person in 2 million is infected (*Science of the Total Environment*, doi.org/ds22).

Although such testing won't tell you who is infected, it will reveal which towns – or even which districts within a town – are home to carriers.

Halden says this would then allow for more targeted testing of individuals. "The numbers I'm crunching show you could begin to analyse 2 billion people for coronavirus right now," he says.

"It sounds like an economic way to get a broad understanding of how widespread the disease is," says Rolf Lood at Lund University, Sweden.

Lood is cautious about Hart and Halden's figures, because some carriers shed up to 200 times more virus than others, but he thinks the technique could be used to quickly assess how widespread the virus is on a regional scale. ▮

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Interview Contact tracer

Tracking down coronavirus

Covid-19 contact tracers are part healthcare worker, part detective and part call centre operative, finds **Adam Vaughan**

THE UK has announced plans for a large-scale contact tracing programme to help the country exit the coronavirus lockdown, with reports that thousands of people are to be recruited.

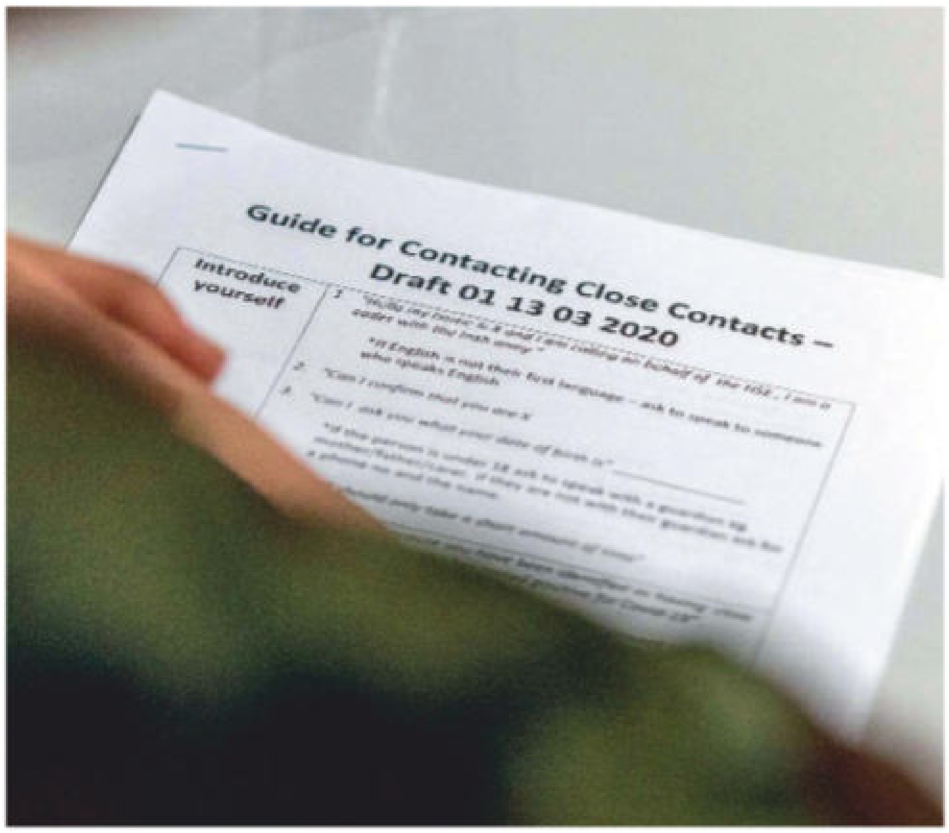
Other countries are already running such operations. In some, such as South Korea, tracers are able to access credit card transactions, phone GPS data and CCTV in an effort to track down everyone an infected person may have come into contact with.

Meanwhile, places like Ireland, Germany and the US are interviewing people who tested positive for covid-19, to work out who they may have infected and to inform those possible contacts.

The role of a contact tracer is unusual. It is part healthcare worker, part detective and part call centre operative. To find out what the job is really like, *New Scientist* spoke with someone who recently spent a month as a contact tracer in Ireland, which has nine contact tracing centres that make thousands of calls a day.

"It was very rewarding. I don't really like the wartime analogy, but it did feel like contributing to the national effort," says the tracer, who doesn't want to be named.

Calls were split into three groups. The first was made by healthcare professionals telling people they had tested positive for covid-19. The second, handled by the tracer, was a call to the same person, to establish close contacts since symptoms appeared – later changed to 48 hours before symptoms appeared. Close contacts were defined as someone within 2 metres for 15 minutes or longer, or within an enclosed space for more than 2 hours.



Guide for Contacting Close Contacts – Draft 01 13 03 2020

Introduce yourself

PAUL FAITH/AFP VIA GETTY IMAGES

Contact tracers in Ireland use a script to gather information

Working out all the possible contacts wasn't always easy. "If you ask someone to go through a list of close contacts they've had over the last 14 days – or even longer, in some cases – they won't come up with a very complete list," he says.

To get more information, the tracers used a script to walk people through their day-to-day contacts. One doctor the tracer called had already drawn up a list of names and numbers, but asking him to talk through his days revealed he had overlooked a few contacts.

The third group of calls was to the people who had been potentially exposed to the virus, advising them to self-isolate.

The number of contacts per person was rarely more than two. The tracer thinks the number may have been low because many interviewees were healthcare workers who isolated at the first sign of symptoms, and because Ireland was relatively quick to begin social distancing.

People informed of possible contacts were only given the date of the contact, not names or locations, but it was often easy for them to guess. "It was usually very obvious, because it was often someone living in the same house as them or a family member that they knew had tested positive," the tracer says.

> **"I don't really like the wartime analogy, but it did feel like contributing to the national effort"**

The tracer had no access to data beyond a patient's date of birth and no powers to compel people to give up details. All information provided was given voluntarily and taken at face value, without fact-checking.

When calling people to suggest they self-isolate, the tracer had no way to force people to do so. "We had absolutely no powers beyond giving them advice." Fortunately, he never encountered any defiance. "Everyone was quite trusting and wants to help."

The job requires a sensitive manner because many people who had tested positive for covid-19 were worried about who they had passed it on to, such as one woman who has a grandmother in her 90s.

Others feared they had been irresponsible, such as a healthcare worker who had been seeing her boyfriend regularly, despite him fearing he may have had the virus. That is why scripts were designed not to make people feel guilty. "We wanted them to be as open as possible because that's what's important," says the tracer.

Many people were reassured or helped, he says, such as a woman with mild symptoms who was fast-tracked for a test after calls established a confirmed contact.

Like most jobs, it had frustrations. Chief for the tracer was the few number of calls he was able to make – around five a day – partly due to bottlenecks stemming from a lack of healthcare professionals to make the first calls.

Another was the speed at which tests led to results and potential contacts being called: often more than 10 days since they may have been exposed to the virus. In that sense, the contact tracing was more of a formality, he says. "I don't think it was very effective in stopping the spread."

A spokesperson for Ireland's Health Service Executive (HSE) says it has cut the turnaround for testing. "In March and early April, the HSE was processing a large number of covid-19 tests. The volume of people who presented for testing in March resulted in a delay in testing and thus in the reporting of test results and contact tracing. Significant work and investment has now ensured Ireland has a high volume of capacity for testing using quality labs." ▮

Analysis **Antibody testing**

The problems with so-called immunity tests

Initial antibody testing surveys suggest more people have been infected than we thought. But we need to be cautious about these results, reports **Michael Le Page**

ANTIBODY tests hold the promise of telling us how many people are already immune to the coronavirus. Unfortunately, serious issues with antibody testing mean we need to be very careful about how we use them.

So far, almost all coronavirus testing has looked for the presence of the virus in swabs of the nose or throat. But not every suspected case is tested in this way, so the actual number of cases in any country or region must be higher than official figures suggest.

The question is, how much higher? This matters because it can help indicate the best strategy for removing lockdowns and social distancing measures. In theory, tests that show how many people have antibodies against the coronavirus in their blood could tell us this.

Numerous research teams and companies worldwide are developing tests for antibodies, and some are already being used, but it is unclear how accurate most of them are, and few have undergone any kind of independent validation. The UK paid millions upfront for 2 million home antibody testing kits, as revealed mid-April by *The New York Times*, before independent tests suggested the kits were unreliable.

VLADIMIR GERDO/TASS VIA GETTY IMAGES

Blood is collected for antibody testing in a Moscow medical centre

But enthusiasm for antibody testing has remained high for two reasons: some kinds of antibody tests are easier to do than swab tests, and they may be able to tell us how many people are now immune to the coronavirus. This is a big may however – it isn't yet clear what role antibodies play in immunity to the coronavirus. On 24 April, the World Health Organization released a statement saying that no study has yet "evaluated whether the presence of antibodies to [the virus] confers immunity to subsequent infection".

Nevertheless, many have begun to use antibody tests to try to get a picture of how many people have caught the coronavirus so far. The initial findings have been making headlines, even though many of these studies haven't been published yet, let alone peer-reviewed.

Some antibody surveys suggest that far more people have been infected than expected. For instance, a study in Santa Clara county, California, where just 50 deaths have been attributed to the virus so far, claimed that up to 4 per cent of people there had been infected – up to 85 times the official figure – based on a survey of 3000 people (medRxiv, doi.org/dskd).

But the Santa Clara study and similar work elsewhere has come under fire. We should not be making policies based on studies that haven't been properly reviewed, says Daniel Larremore at the University of Colorado, Boulder. "It really matters that we get these things right."

There are two main issues with antibody surveys. The first is that when only a tiny percentage of a population has been infected, false positives can lead antibody testing to wildly overestimate the number of people who have encountered the virus.

The second is that it is hard to recruit and test a representative sample of the population, so results can end up being greatly skewed.

Beyond these issues, to refer to antibody testing as "immunity tests" is premature – we still don't know if it is possible to have covid-19 twice. ▮

Vaccines

Trials of BCG vaccine will test for covid-19 protection

WHILE a coronavirus vaccine is still a way off, some believe we may have a stopgap in the BCG vaccine, which protects against tuberculosis (TB).

In countries with routine BCG vaccination, the pandemic appears to be less severe. This could be due to a long-standing but unproven hypothesis that the vaccine is a general immune-system enhancer.

The Max Planck Institute for Infection Biology in Berlin is planning a clinical trial of a genetically modified version of BCG that has been shown to make mice more resistant to viruses like flu. The trial has regulatory approval and should start this week.

If it succeeds, millions of doses could be made available in a very short time, says Adar Poonawalla at the Serum Institute of India, a private company that is partnering with the Max Planck Institute to develop the vaccine. BCG trials have also begun in the Netherlands and Australia.

Some countries, including the US and Italy, have never had a national BCG programme and others phased theirs out as TB became less of a concern – the UK stopped in 2005.

Gonzalo Otazu at the New York Institute of Technology has found that countries where the BCG vaccine is used have fewer covid-19 cases and/or deaths. He analysed the link using up-to-date information on worldwide BCG programmes.

"The correlation was very clear," he says. But he cautions that it is too early to recommend action. "BCG vaccination is a potential new tool in the fight against covid-19, but we have to wait for the results of the ongoing clinical trials," he says.

> **"BCG vaccination is a potential new tool in the fight against covid-19, but we have to wait for trials"**

Lone Graff Stensballe at the Danish National University Hospital is sceptical, both of the general immune-enhancing claims for BCG and the specific covid-19 idea. "It has not been possible to detect such beneficial non-specific effects of BCG in well-designed studies," she says. "My advice would be to invest our scarce resources in other preventive measures." ▮

Graham Lawton

Diet

Epigenetic hints for the health benefits of drinking coffee

Alice Klein

DRINKING coffee may change how some of our genes are expressed, which could help explain its numerous health benefits.

Studies suggest that people who drink coffee are less likely to get certain illnesses, such as heart disease, but we don't know why. To learn more, Mohsen Ghanbari at Erasmus University Medical Center in Rotterdam, the Netherlands, and his colleagues looked at whether coffee consumption is associated with the presence of certain epigenetic markers – chemical tags on DNA – that increase or decrease the activity of certain genes that may influence health.

They looked for particular markers known as methyl groups in almost 16,000 people of European and African American descent in the the US and Europe. The more cups of coffee a person drank per day, the more likely they were to have altered levels of methyl groups at 11 particular DNA sites. This was still true after age, body mass index, smoking, alcohol consumption and other factors that may have influenced the results were taken into account (bioRxiv, doi.org/dsts).

The methyl groups tended to be attached to genes that play roles in digestion, processing harmful chemicals and controlling inflammation.

> "This provides tantalising clues to how epigenetics could explain some of coffee's health benefits"

These are "tantalising clues" to how epigenetics could explain some of coffee's health effects, says Peter Molloy at the Commonwealth Scientific and Industrial Research Organisation in Australia. But more studies are needed to prove that the markers alter the activity of these genes and that this affects our health, he says.

Solar system

Glut of suspected interstellar asteroids discovered

Jonathan O'Callaghan

DOTTEDZEBRA/ALAMY

An artist's rendition of 'Oumuamua, an interstellar asteroid

NINETEEN objects orbiting our sun may have originated around another star, suggesting interstellar objects in our solar system may be more common than previously thought.

Fathi Namouni at the Côte d'Azur Observatory in Nice, France, and Helena Morais at São Paulo State University in Brazil simulated how the orbits of objects called centaurs have evolved since the dawn of the solar system. Centaurs are found between Jupiter and Neptune and have similarities to both asteroids and comets.

They found that the orbits of 17 centaurs could be explained by them being captured by our sun early in its life. A further two asteroids orbiting further out past Neptune, known as trans-Neptunian objects, also appear to have a similar origin.

"We followed their motion back in time to 4.5 billion years [ago] and found that all of these objects [were] perpendicular to the plane of the solar system," says Namouni. "This tells us they could not have been part of the solar system and must have been captured."

The researchers believe that these 19 objects were captured when the early sun was surrounded by a protoplanetary disc of dust and gas. This material could have slowed incoming objects from other young stars born nearby, although the 19 in question aren't thought to all have the same origin (*Monthly Notices of the Royal Astronomical Society*, doi.org/dst3).

To date, only two interstellar objects have been definitively identified in our solar system: the asteroid 'Oumuamua in 2017 and the comet 2I/Borisov in 2019.

It is thought that many such interstellar objects are constantly traversing our galaxy, and some of them also pass through our solar system. However, as these hurtle past our sun at high speed, we usually only have a brief window to study them. If numerous interstellar objects are permanently orbiting the sun, it would open up new avenues to observe objects born around other stars.

Studying them with telescopes should be possible, but using a spacecraft might be more challenging, according to Colin Snodgrass at the University of Edinburgh in the UK, deputy lead on the European Space Agency's Comet Interceptor project. "Any mission [would] need a big rocket to go out there," he says. "There's a reason why we haven't had a mission to any centaur."

Kat Volk at the University of Arizona says it is hard to trace the history of specific objects. "These high-inclination objects are interesting and present a challenge for solar system formation and evolution models, but I don't think an interstellar origin is convincing based on this work," she says.

Namouni, however, says that the centaurs are on stable orbits, and he is very confident that all 19 objects are of interstellar origin. "From my point of view, they are confirmed," he says. "What we need to do is to go and observe them and try to see if they look like solar system asteroids or not."

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Health

Brain implants may help anorexia

Inserting electrodes into the brain improved symptoms in a small trial

Alice Klein

SOME women with severe anorexia have returned to a healthy weight and feel less anxious and depressed after having electrical devices implanted into their brains, according to a small study. But more research is needed before the treatment can be recommended for wider use.

About one in five people with anorexia nervosa, who are mostly women, die of the illness and there is a lack of effective treatments. Imaging studies suggest that certain brain circuits may underlie the fear of gaining weight and compulsion to self-starve.

Bomin Sun at Shanghai Jiao Tong University School of Medicine in China and his colleagues wondered whether they could disrupt these circuits by electrically stimulating a part of the brain known as the nucleus accumbens. This brain region helps us to learn from experience, but in people with anorexia it seems to form abnormal connections with other brain regions.

The team recruited 28 women with at least a three-year history of anorexia who hadn't improved following standard treatment. The women had an average body mass index (BMI) of 13; a BMI of less than 18.5 is considered underweight. The researchers surgically implanted electrodes into the nucleus accumbens on both sides of the women's brains. They connected the electrodes by wires to a battery inserted beneath the collarbone, to continuously stimulate the nucleus accumbens.

Electrodes that stimulate the brain are used for a variety of conditions

REUTERS/BERNADETT SZABO

Over the next two years, the average BMI of the participants increased to 18 and almost half regained a BMI of 18.5 or above. They also reported feeling fewer anxiety and depression symptoms and experiencing less of an effect on their social lives (*Brain Stimulation*, doi.org/dst7).

"This is a very promising result," says Philip Mosley at QIMR Berghofer Medical Research Institute in Australia. But the study didn't include a placebo group for comparison, meaning it isn't possible to rule out that the participants' improvement was simply because they expected the treatment to work, says Mosley.

He and his colleagues are about to launch a trial of the same treatment in which they will control for the placebo effect. They will implant electrodes into the nucleus accumbens of 10 people with severe anorexia, but for the first four months, only half will have the electrodes switched on. Participants won't know if their electrodes are on or off. If the improvement is greater when the electrodes are on, it will make it easier to tell if the treatment is working.

Brain surgery may seem like an extreme treatment, but for people with severe anorexia, it may be better than the alternative, which is often death, says Mosley.

"Anorexia has the highest mortality rate of any psychiatric illness – it's an astonishingly sinister disease," he says. "We hope this treatment will help some people who are at the sickest end of the scale and had years of suffering and tried all other evidence-based treatments." ▮

Solar system

Proposed Planet Nine probably doesn't exist

THINGS aren't looking so good for Planet Nine. Astronomers have been seeking signs of a purported giant planet in the outer reaches of our solar system since 2014, but new observations hint it may not exist.

In 2014, astronomers noticed that rocks in the outer solar system called extreme trans-Neptunian objects, or eTNOs, seemed to be inexplicably clumped together. That, along with their odd, elongated orbits, may be explained by the gravitational influence of a planet with five to 10 times Earth's mass.

But a new study brings into question whether eTNOs are actually clumped. Pedro Bernardinelli at the University of Pennsylvania and his colleagues analysed data from the Dark Energy Survey on seven eTNOs and found no evidence for any unexpected clumping – so no reason to dream up a new planet (arxiv.org/abs/2003.08901). "We would not have formulated the Planet Nine idea if our data was the only data that existed," says Bernardinelli.

"These results don't worry me too much," says Mike Brown at the California Institute of Technology, who was one of the formulators of the Planet Nine hypothesis and leads a team looking for it. All the data we have on eTNOs, when viewed together, still points to the possibility of a ninth planet, he says.

"We would not have formulated the Planet Nine idea if our data was the only data that existed"

We need to find many more eTNOs to get close to a definitive answer, but their elongated orbits, which take them extremely far from the sun, make them tough to spot. If we eventually find that they aren't clumped up and there is no evidence for Planet Nine, these unusual orbits are hard to explain.

"Even if they're not clustered, we still have to explain how they got there," says Bernardinelli. ▮

Leah Crane

Microbiology

Raw pet food can contain drug-resistant bacteria

Clare Wilson

PET dogs and cats could be passing on potentially deadly antibiotic-resistant bacteria to their owners.

Two studies have found that some pets harbour microbes that can withstand antibiotics, including one used as a last resort. Other work suggests resistant bacteria are found in pet food, especially the raw type.

Ana Freitas at the University of Porto in Portugal and her team analysed raw, tinned and dry dog food. Microbes resistant to multiple antibiotics were discovered in all nine samples of raw food, one of the 22 tinned samples and in none of the 15 dry foods.

"These bacteria can be a reservoir in pets' and humans' gut of resistance genes able to be transferred to other [disease-causing] bacteria," she says.

Faecal samples taken from pets and their owners suggest transfer to humans may happen. Carolin Hackmann at the Charité – University Hospital Berlin, Germany, and her colleagues found that 23 out of 45 dogs had antibiotic-resistant bacteria, as well as one of 71 cats. In two of the dogs, these matched bacteria strains in their owners' stool. This suggests pets aren't a major source of drug-resistant microbes in their owners, she says.

In a Portuguese study, two out of 55 dogs had gut microbes with resistance to colistin, a last-resort antibiotic that can be used to treat bacterial pneumonia. One dog shared this strain with its owner, although it is unknown which direction the microbe had travelled.

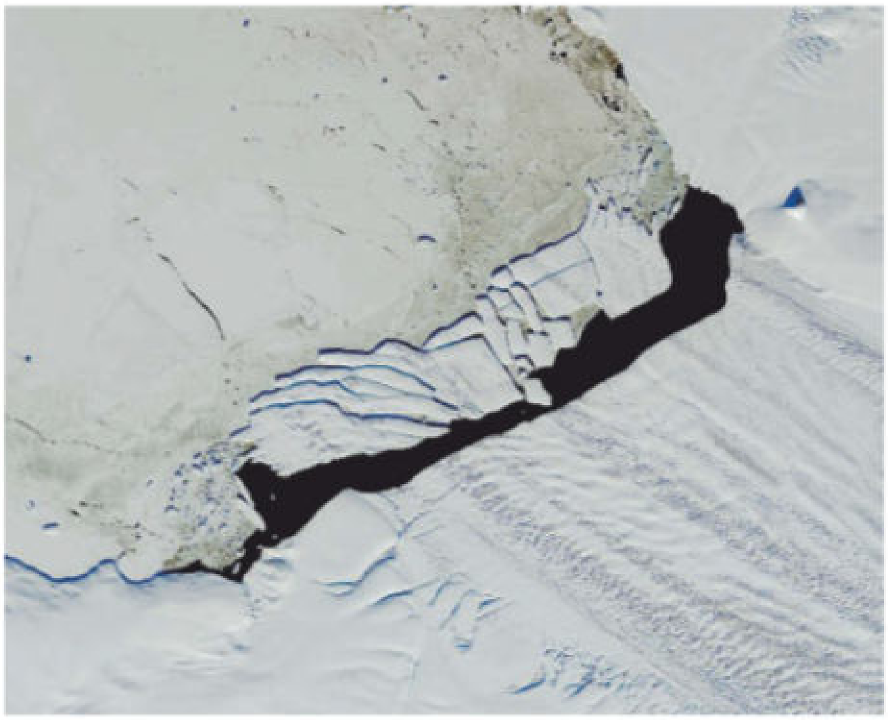
All the research was submitted to the European Congress of Clinical Microbiology and Infectious Diseases, which was due to be held in France in April but was cancelled.

Brendan Clarke, head of the Raw Feeding Veterinary Society, says a survey of pet owners suggested it was very rare for people to catch infections from raw pet food. ▮

Climate change

Antarctic glacier at risk of unpredictable collapse

Michael Marshall



RKIVE/ALAMY

Pine Island glacier is a weak point in the Antarctic ice

A MAJOR Antarctic glacier is at risk of disintegrating irreversibly if it passes a key tipping point, which could trigger the collapse of the entire West Antarctic ice sheet – and we can't say when it might happen.

Pine Island glacier is one of two glaciers flowing into Pine Island Bay, part of the Amundsen Sea off West Antarctica. The other is Thwaites glacier. Both have retreated rapidly due to climate change, contributing to rising sea levels.

"Of all glaciers around Antarctica, we believe Pine Island glacier has contributed most, so far," says Sebastian Rosier at Northumbria University in the UK. "People are very concerned."

Worse, the two glaciers are the weak point of the West Antarctic ice sheet, which sits on bedrock below sea level. A dramatic glacier retreat could let water get under the ice and thus collapse the entire ice sheet, leading to more than 3 metres of sea level rise, over centuries.

The main reason the Pine Island glacier is retreating is a current of warmer water that now periodically flows under its floating tip, melting it from below. Because the main part of the glacier sits on rocks that are below sea level, there is nothing to stop this warmer water getting ever further under the glacier.

Rosier and his colleagues simulated the glacier's behaviour as the ocean water at its tip slowly warmed. They found that it passed through not one but three tipping points. The first two both led to rapid ice loss, even if the ocean was later cooled. The third caused the glacier to collapse entirely. This couldn't be stopped by cooling the ocean (EarthArXiv, doi.org/dstt).

1.2°C

Amount of ocean warming that could trigger a last tipping point

"Tipping point three is sort of game over," says Ted Scambos at the University of Colorado in Boulder.

In the model, the third tipping point occurred when the ocean water had warmed by 1.2°C. A 2014 study found that the Amundsen Sea is warming by 0.1 to 0.3°C per decade.

However, Rosier says the 1.2°C threshold is only "a rough ballpark". He emphasises that the simulation deliberately warmed the ocean slowly, to tease out the tipping points.

"It's highly likely that things might happen over a quicker period of time," he says. Rapid ocean warming could even trigger a cascade, in which the first tipping point caused enough melting to unleash the second, and then the third.

The real challenge is that the Amundsen Sea isn't warming as if a thermostat were being turned up, says Scambos. Instead, warmer water that used to be kept out by currents and winds is entering in pulses, controlled by shifts in winds across the Pacific Ocean.

Could we see the tipping point coming? In the model, the researchers were able to spot warning signs: Pine Island glacier became slow to respond to perturbations in ocean temperature. But they needed 300 years of data for this to work. Detailed records of the glacier only go back to the 1970s, with a smattering of older ones. That is a problem, says Rosier.

It may be possible to find out how the glacier behaved earlier in its history by studying sediment cores from the ocean floor just off Antarctica, says Scambos. This could reveal when the ice was grinding over the seabed, and when the seabed was exposed to water. ▮

Planets

Giant pumice raft on ancient Mars

A mysterious geological feature may have floated across an early Martian ocean

Jonathan O'Callaghan

A HUGE floating raft of volcanic rock called pumice may have drifted across an ancient Martian ocean and created one of the most mysterious features we can see on the planet's surface today.

The Medusae Fossae Formation (MFF), found near Mars's equator, comprises about 5000 kilometres of rolling hills and mounds. Scientists have suggested that it was made of volcanic ash from the nearby Olympus Mons or Elysium Mons volcanoes.

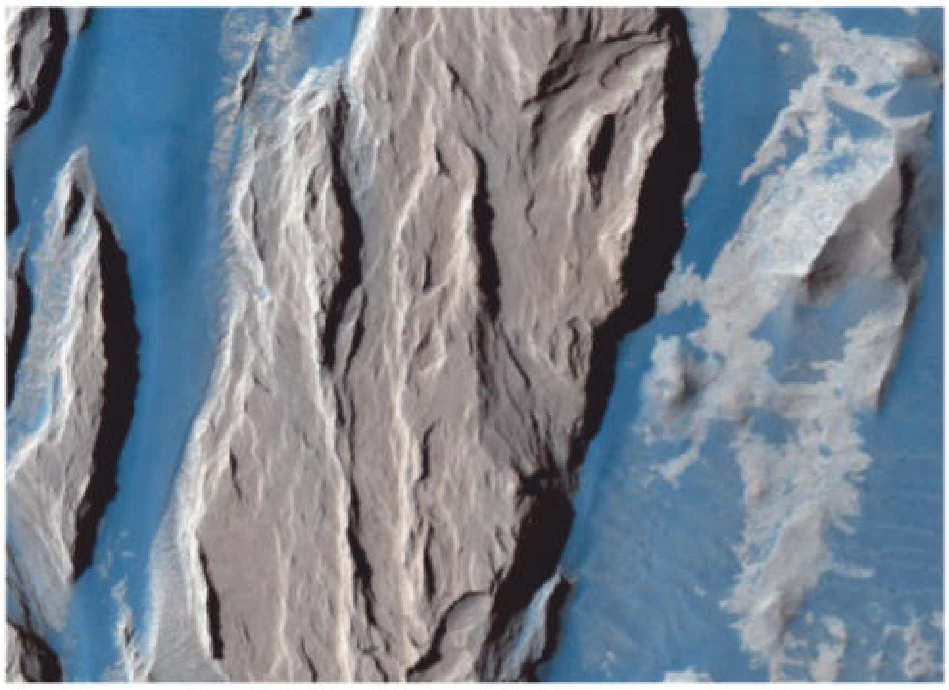
However, the size of the MFF poses some problems for this hypothesis. "It's enormous, over a million square kilometres of land area covered by [an estimated] million cubic kilometres of ash," says James Zimbelman at the Smithsonian Institution in Washington DC. "That's many orders of magnitude larger than the largest volcanic eruptions we know here on Earth."

Instead, Zimbelman and Peter Mouginis-Mark at the University of Hawaii looked at whether a raft of pumice rather than ash could have created it. Mouginis-Mark first proposed the idea in 1993, before subsequent images from Mars-orbiting spacecraft provided new evidence.

Pumice is a light and porous volcanic rock produced when lava interacts with water and rapidly cools, trapping bubbles of gas in it. On Earth, it can build up to form vast floating rafts, such as one covering 150 square kilometres seen on the Pacific Ocean in 2019.

Evidence of landslides on Olympus Mons suggests a similar process could have happened on Mars, say the researchers. The pumice would have built up before breaking away, drifting across a theorised ancient Martian ocean and coming to rest at a shoreline.

The Medusae Fossae Formation covers over a million square kilometres



NASA/JPL-CALTECH/UNIV. OF ARIZONA

"There isn't a volcano nearby that appears to have exploded with the volume of material [needed for the volcanic ash idea]," says Mouginis-Mark. "So we started to talk about, well, if you've got these rafts of pumice floating around on a palaeo-Martian ocean, where would they go?"

Evidence for such an ocean is debated, but if it did exist, it would probably have been at least a few hundred metres deep, spanning Mars's northern hemisphere. A strong wind, possible due to the thicker atmosphere at the time, from the south-west could have transported a floating pumice raft 4000 kilometres from Olympus Mons to where the MFF is found today (*Icarus*, doi.org/dsv9).

Kevin Lewis at Johns Hopkins University in Maryland, who wasn't involved in this research but previously worked on the volcanic ash origin of the MFF, says the pumice raft idea is "not totally outlandish" and is worthy of further investigation. "It's certainly an interesting and creative new hypothesis," he says.

If true, it could sway the debate on the presence of ancient large oceans on Mars, and potentially its previous suitability for life. "The rafted pumice proposal really requires an open, unfrozen body of water," says Lewis. "It would certainly provide some pretty interesting information about the Martian palaeoclimate in terms of water abundance and maybe habitability." ▮

Military technology

US Navy has scheme to make 'ghost planes' in mid-air

AT OVER 600°C, a jet engine's exhaust stands out like a beacon when seen in infrared, making it a target for heat-seeking missiles, but a US Navy device might be able to thwart such missiles with ghost images projected in mid-air.

The traditional defence has been to eject hot flares to draw missiles away from a plane. This new method uses lasers. When focused to a point, a laser can produce a spot or filament of ionised gas, known as a laser-induced plasma.

Alexandru Hening at the Naval Information Warfare Center Pacific in California is using lasers to create an array of plasma columns in the air. These are rastered like the beam in an old cathode-ray screen to create two or three-dimensional images in mid-air of ghost aircraft that can distract incoming missiles.

The patent describing the work was published in February, although it was filed in 2018. The exact status of the work and how close it is to operational deployment are unknown. The US Navy didn't respond to requests for comment.

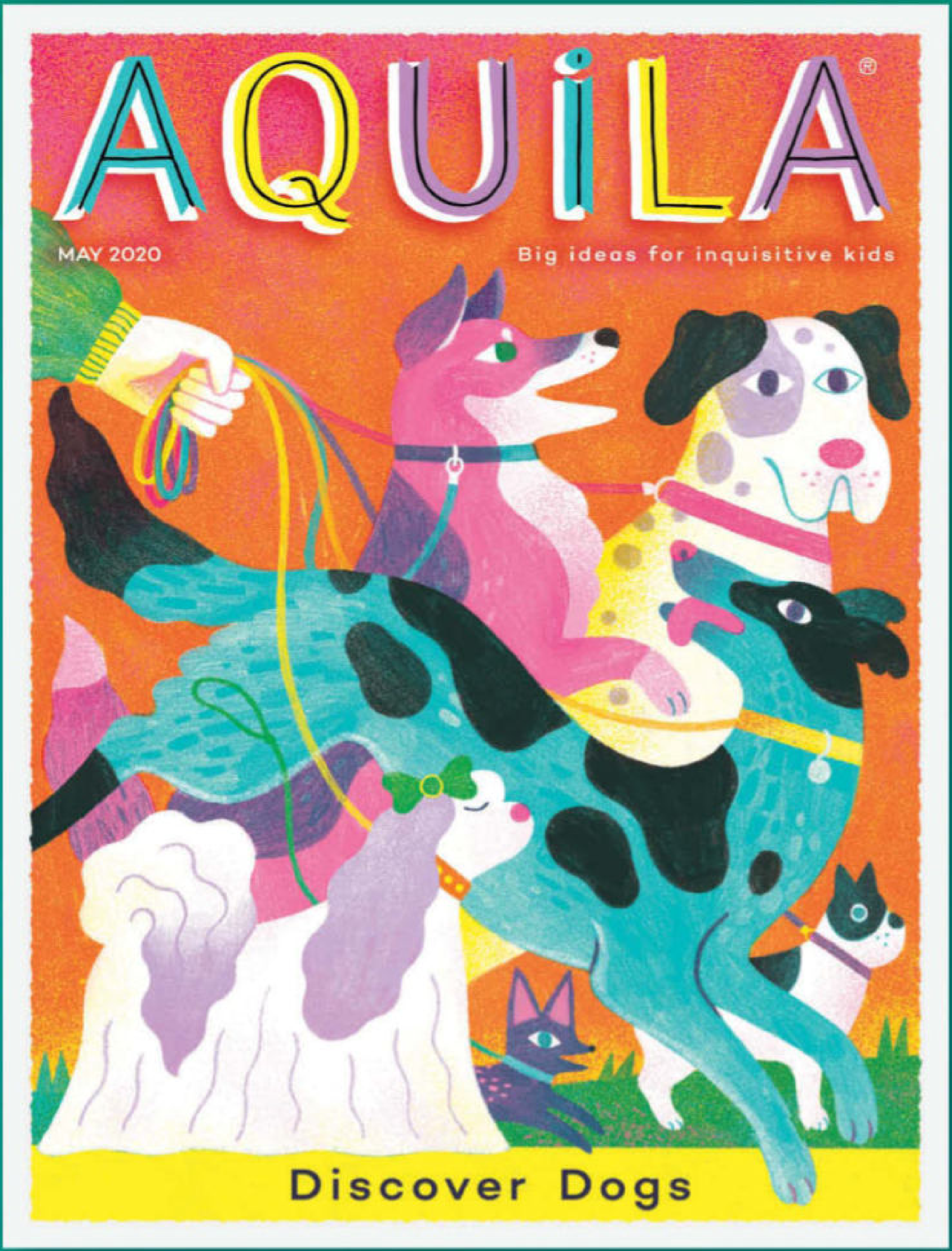
In principle, by tuning the plasma, any desired wavelength could be made, from radio to gamma rays, so the device could be adapted to fool future sensors. The challenge is likely to be producing a stable plasma with a powerful enough infrared output to be effective.

"Lasers focused to a point produce ionised gas that can be displayed in 2D or 3D images in the air"

Gianluca Sarri at Queen's University Belfast in the UK believes the plasma decoy is plausible in theory. He says the mechanism is well known and widely used in laser-plasma applications. Existing high-power lasers work at shorter wavelengths, which would be unsuitable, but a powerful mid-infrared laser could create a suitable plasma column, he says. ▮

David Hambling

AQUILA CHILDREN'S MAGAZINE



The MAY issue of AQUILA investigates the story of **Man's Best Friend** – warts and all! Find out why dogs come in all **shapes, colours and sizes** – and what's with the wet nose? Children can read about vegetarian dogs and the fearsome **'Black Shuck'**. PLUS: discover the history of the **American Hot Dog**, find out **'What kind of canine would you be?'** and bake some dog biscuits.

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Geology

Ancient tectonics may have had a role in the rise of life

THE drifting of continents may have got under way on Earth at least 3.2 billion years ago and could have played a part in the evolution of life.

Plate tectonics helps recycle key elements and maintains a relatively stable temperature, which are important to life. Previously, the earliest evidence for plate tectonics was around 2.8 billion years old.

Now Alec Brenner and Roger Fu at Harvard University and their team have studied a 3.2-billion-year-old volcanic rock formation in Western Australia called the Honeyeater basalt (pictured). They used a microscope to visualise magnetic fields of a mineral called magnetite.

The team looked at a series of rock samples formed over a period of about 180 million years. The magnetic signal within these was shaped by Earth's magnetic field at the time the mineral formed. Changes in the direction of the magnetism over the period suggest these rocks moved some 2.5 centimetres a year over the 180 million years (*Science Advances*, doi.org/dstq).

That is similar to the speed at which continents move today, says Brenner. "About 3.2 billion years ago, at least some of Earth's crust was moving fast enough to suggest that plate tectonics was driving that motion," he says.

The team checked that the magnetic signal in the rock samples really is from the time that the rock originally formed instead of from a later event. Fu says he is confident that the signal is indeed pristine.

Brenner says it may be possible that plate tectonics goes even further back. **Michael Le Page**

Global warming

Record methane leak from US oilfield

SATELLITES have revealed that the fracking heartland of the US is leaking a powerful greenhouse gas at a record-breaking rate.

The methane escaping annually from the oil and gas wells of the Permian basin, which straddles Texas and New Mexico, has the potential to warm Earth by almost as much as the carbon dioxide all homes in the US release each year.

Methane, also known as natural gas, is pumped out of the region's wells and captured for use, but the satellite analysis, led by Yuzhong Zhang at Harvard University, has shown that 3.7 per cent of that gas is lost to the atmosphere.

Zhang and his team analysed state-of-the-art measurements of methane columns in the atmosphere taken over 11 months during 2018 and 2019 by the satellite-based TROPOMI system. Launched in 2017, it started sending back data in 2018 that is much higher resolution than previous surveys and provides daily coverage.

The leakage rate they found is more than twice that assumed by the US Environmental Protection Agency, well above the average 1.9 per cent rate for 11 other major US basins and higher than that recorded in any oil and gas field there before (*Science Advances*, doi.org/dsvc).

The findings undermine the dominant narrative in the US that its energy sector has become much cleaner in recent years as it switched to burning natural gas instead of coal for power.

"Any emission rate greater than 1 per cent or so is significant in terms of the greenhouse gas consequences of using natural gas. And at 3.5 per cent or 3.7 per cent, natural gas is far worse for the climate than is coal," says Robert Howarth at Cornell University in New York, who wasn't involved in the research. **Adam Vaughan**

Health

Premature birth may lead to heart issues

PEOPLE born prematurely may have weaker hearts that recover less well after exercise. This could help explain increased incidence of cardiovascular disease among prematurely born individuals.

Adam Lewandowski at the University of Oxford and his team studied adults aged 18 to 40, 47 of whom were born moderately prematurely – at between 32 and 36 weeks of pregnancy – and 54 who were born at term, approximately 40 weeks.

They measured heart and lung function before, during and after intense exercise on a cycling machine. Peak oxygen uptake during exercise – a key indicator of heart and lung capacity – was 16 per cent lower on average in the pre-term individuals, compared with those who were born at term.

Two minutes after peak exercise, heart rates had recovered by 19 per cent more in the group of people born at term compared with the pre-term group (*European Heart Journal – Cardiovascular Imaging*, doi.org/dst6).

A reduced oxygen uptake and slower heart rate recovery are both risk factors for cardiovascular disease, says Lewandowski.

This adds to emerging evidence indicating that pre-term birth leads to long-term vulnerability to heart disease, says Mary Jane Black at Monash University in Australia. **Layal Liverpool**

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Really brief

BATTELLE MEMORIAL INSTITUTE

Brain implant helps combat paralysis

A man with a severe upper spinal cord injury is now able to grasp and feel objects again. Researchers in the US used an implant to record brain activity that is sent to a processor that decodes these signals into movements. The system then uses bands around the forearm to electrically activate his hand muscles (*Cell*, doi.org/dstr).

AI spots sea plastic in satellite images

An AI trained on images from the European Space Agency's Sentinel-2 satellites can tell ocean macroplastics – fragments more than 5 millimetres in size – from other materials such as sea foam and seaweed with 86 per cent accuracy. This could help clean-up efforts (*Scientific Reports*, doi.org/dssd).

Two-layer paint can keep buildings cool

Paint layered on a polymer that reflects infrared light may make buildings more energy efficient. An object coated with a black version of this two-layered paint stayed 16°C cooler than an object covered in regular black paint getting the same sunlight (*Science Advances*, doi.org/ds2z).

Social media

AI can root out bots on Twitter

ARTIFICIAL intelligence is being used to tell human users from fake, automated accounts on Twitter.

Emilio Ferrara at the University of Southern California and his colleagues have trained an AI to detect bots on Twitter based on differences in patterns of activity between real and fake accounts.

The team analysed 8.4 million tweets from 3500 confirmed human accounts and 3.4 million tweets from 5000 bots.

The researchers found that human users replied between four and five times more often to other tweets than bots did. Real users gradually become more interactive, with the fraction of replies increasing over the course of an hour of Twitter use.

The length of tweets by human users also decreased as sessions progressed. Bots, on the other hand, show no changes in their interactivity or the length of information they tweet over time.

The team also analysed the amount of time between any two consecutive tweets from a single user. When this distribution is plotted, bots showed spikes for set time gaps, such as tweeting at 30-minute or 60-minute intervals.

The team then combined these findings to train an existing bot-detection algorithm, called Botometer. The resulting AI was significantly more likely to accurately detect fake accounts (*Frontiers in Physics*, doi.org/dsvg).

One of the study's limitations is that the Twitter data the team analysed is from three years ago. In that time, it is possible that bots have become more human-like in their activity patterns. **Donna Lu**

Climate change

MARCUS YAM/GETTY IMAGES

Expect more extreme flooding from hurricanes

HURRICANE Harvey caused terrible flooding in the US in 2017, killing 68 people. One reason it hit regions including Texas (pictured) so hard is that it moved unusually slowly, affecting the same area for days.

As the world warms, there are going to more slow-moving storms like this, according to Gan Zhang at Princeton University and his colleagues. They ran about 100 high-resolution simulations of how tropical cyclones behave in three types of conditions: those in the past from 1950 to 2000, those similar to the present and those in various future scenarios.

They saw a marked slowing of storms as the world warms, due to a poleward shift of the mid-latitude westerly winds (*Science Advances*, doi.org/dstz). It is these prevailing winds that push cyclones along and determine how fast they travel. This slowing will raise the risk of extreme flooding that, among other things, could break dams and spread pollution, says Zhang.

Other studies suggest that warming will also lead to tropical cyclones becoming stronger, producing more rainfall, intensifying faster – giving people less time to prepare – and forming in and affecting a wider area than they have previously. MLP

Technology

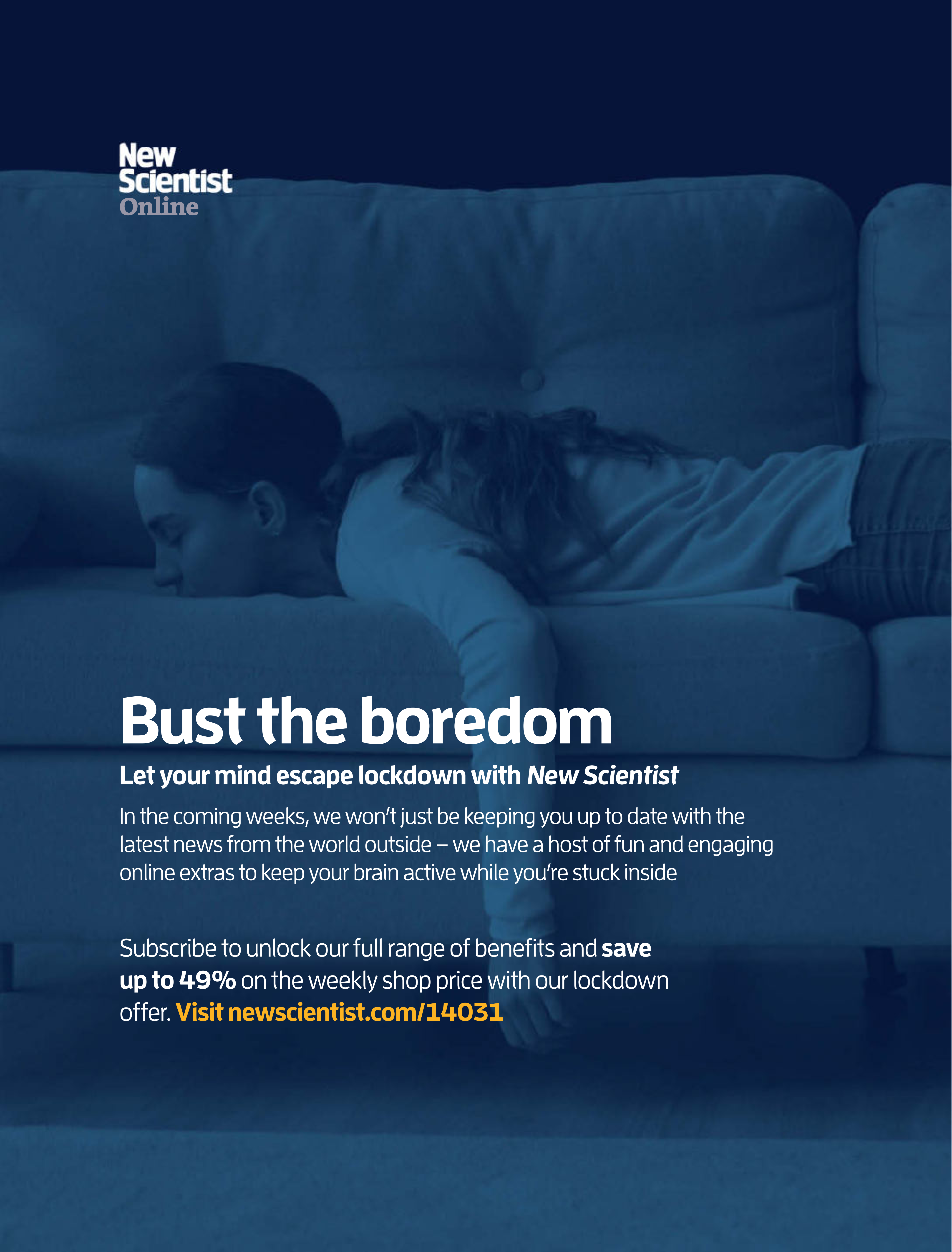
Phone enables light, cheap DNA detector

A CHEAP, lightweight and smartphone-powered detector can now identify DNA in blood, urine and other samples.

This is usually done in labs using expensive, specialised equipment. Ming Chen at the Army Medical University in China and his team have developed a portable version using 3D-printed parts that attach to a standard smartphone. It can detect DNA based on characteristic mutations or short sequences. It costs about £8 to make, weighs 60 grams and takes 80 minutes to work.

The detector is heated by the phone. Samples can be loaded into the detector and mixed with pre-filled chemicals that light up or change colour if there is any DNA that matches. The signals are detected by a lens and light box and the phone displays the result.

Tests showed that the device can detect conditions like alpha- and beta-thalassemia in blood. It also identified people with a gene that makes them more susceptible to alcohol intoxication using cheek swabs, and can spot *E. coli* in urine, milk and river water. Overall, the accuracy of the device was about 97 per cent that of standard lab methods (*Science Advances*, doi.org/dsvp). **Alice Klein**



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Views

The columnist
Covid-19 is partly the result of greed, says **Graham Lawton** p22

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Seeking silver linings amid the coronavirus pandemic p24

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Iconic machines from the first 25 years of home computing p26

Culture
Jane Goodall on keeping positive during the crisis p28

Culture columnist
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Comment

Mental health in trouble

We are already seeing the pandemic's effects on mental health, and we need to act urgently to avoid a full-blown crisis, says **Sam Howells**

JOSIE FORD

UNDER normal circumstances, around one in five people will experience a mental health problem each year in the UK. However, these are not normal circumstances.

Because of the coronavirus pandemic, many people cannot leave their homes except to buy food or exercise briefly. They cannot see their friends or family, or go to work, and the near-term outlook is bleak. This combination is the perfect storm for an increase in mental health conditions and we are already beginning to see signs that an associated mental health pandemic is under way.

I am on the front line. I work as a psychological healthcare professional for England's National Health Service in a programme called Improving Access to Psychological Therapies (IAPT). This is the first point of call for mental health conditions in much the same way that family doctors are for issues with physical health.

We are anticipating explosive growth in mental health problems that far exceeds our current capacity. Serious societal and economic disruption is nearly always associated with a surge in such problems. Within a month of the 9/11 attacks, for example, around 10 per cent of New York residents showed signs of diagnosable major depressive disorder. During the SARS outbreak in 2003, there was a substantial rise in reported cases of depression, anxiety, panic attacks, psychosis and suicidal thoughts in China, for example, although precise figures remain elusive as mental health problems are still often stigmatised.

A growing number of our patients report that isolation and a general sense of physical, social and economic vulnerability are triggering existing and new psychological problems, and the pandemic is hampering our ability to deal with them.

Due to homeworking restrictions, my colleagues and I are relying almost solely on virtual technology to treat people, which hasn't yet been proven at this scale. At the same time, IAPT staff are being diverted into hospitals to bolster overburdened physical healthcare wards.

In my London borough, where the prevalence of mental health conditions is around twice the national average, an atmosphere of unease about the coming months is palpable. There is often a lag of months or years between societal crises and the presentation of mental health issues, so things are likely to get worse before they get better.

There is no easy solution to these problems, but just as social distancing and good hygiene can help flatten the peak of the pandemic, we can also do things to reduce the mental health crisis.

There are many ways of trying to maintain your own mental well-being. Evidence points to the importance of eating and sleeping well, staying active and keeping in regular contact with friends and family. Attempting to maintain a daily routine in which activities are scheduled, and work and leisure are separated, can help to generate a sense of normality.

However, when this isn't enough, it is important to seek help. If people notice persistent symptoms of mental health conditions that have begun to interfere with normal behaviour, they shouldn't be afraid to request support. Many places still offer a range of therapies online, over the phone and via video calls.

Mental health services could be overwhelmed within months, so the UK government needs to act fast. Increasing funding or bolstering services with retirees, volunteers and workers from other healthcare sectors, as we have seen in physical healthcare, could help. But whatever is done, it needs to be done soon. ▮

Sam Howells is a clinician at South London and Maudsley NHS Foundation Trust

No planet B

Time to get thrifty Hyperconsumption is one of the things that got us into this mess. But we have to avoid the temptation to rely on it to get us out again, writes **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*. You can follow him @grahamlawton

WHEN I heard the news that Amazon is making sales of $11,000 every second of the lockdown, my initial reaction was weary resignation. You probably don't eat bushmeat, but Western consumerism adds to the deforestation and habitat destruction that increasingly brings humans into contact with animal viruses. The world is in turmoil due to a virus unleashed in part by greed, and how do we respond? By going shopping.

There was a stab of guilt too: I don't think of myself as a materialist, but I've become a regular user of online retailers, buying things I don't really need to help ease the boredom.

Thankfully, it turns out that my initial reaction was wrong. In the US – where the spree has been likened to Black Friday, the day after Thanksgiving when people go on an online retail bender – consumer spending is actually falling in almost every category.

The little money being spent is going on essentials such as food and household goods and, out of necessity, this is shifting online. Amazon's bounce is not a frenzy but a hunkering down. In that I find hope rather than dismay.

There has been much discussion of the environmental benefits of furloughing the world economy. Oil consumption has gone through the floor and there is increasing talk of a green economic recovery. I'm sceptical. Once we get the all-clear, I think the most likely response will be a rapid push to return to business as usual, encouraged by leaders whose electoral prospects hinge on an economic recovery.

But I also have hope, because the pandemic and its aftermath might permanently shift attitudes away from hyperconsumption.

Consider the enforced changes in my own family's habits. In the era now known as BC – Before Coronavirus – our food shopping worked like this: we decided what we wanted to eat, bought it and ate it. I know that I should have been buying local and seasonal, but habit, convenience and deliciousness won out.

This has been upended. I now avoid the supermarket. The shelves are well-stocked – we owe thanks to staff who keep them that way – but the hassle of queuing, of wearing a mask, of social distancing in the aisles, of lugging the stuff home and then wiping it down (I know the evidence for the necessity and effectiveness of doing this is weak, but better safe than sorry) are a big disincentive.

> **"One outcome of the lockdown may be to make us see that consumption isn't a route to happiness"**

Instead, I now mostly buy food that I stumble across in shops and stalls near my house, and then decide what to cook with it. A couple of days ago, I came home with three aubergines, a bunch of beetroot and some wilted coriander. Not exactly a feast to write home about, but, supplemented by the dwindling contents of my cupboards, they became an excellent curry. It felt like a triumph of thrift and ingenuity. My sister later proudly told me that she fixed a pair of reading glasses with superglue.

I suspect that many people are similarly learning to make do and mend when they can. And if they are anything like me, they are enjoying it too. It turns out that when you are used to hyperabundance, scarcity can be a breath of fresh air.

You can understand why we have created a hyperabundant society. We naturally assume that more of any good thing will make us happier. This is true up to a point, but the psychology of happiness is very clear: humans quickly become satiated by abundance and have to consume ever more just to stand still. This is what economists call the "hedonic treadmill".

Capitalist society has trapped us on a number of hedonic treadmills. Think of those entertainment services that are so welcome right now. Netflix, Spotify and so on are great, but when you can watch or listen to anything, anytime, you end up taking them for granted.

One unexpected outcome of the lockdown, then, is to forcibly knock us off some of our hedonic treadmills and, I hope, cause us to see that endless, unlimited consumption isn't a route to happiness. And with the economic forecasts looking gloomy, this could continue long after lockdown is over. Many people who would have otherwise hyperconsumed their way back to unhappiness won't be able to afford to do so.

I don't think there is a precedent in recent history. The shutdown after the 9/11 terror attacks lasted just days and everything quickly bounced back in most places.

Perhaps instead we need to look to my grandparents' generation, which lived through the second world war and the rationing that lasted until the 1950s. This led to thrifty lifestyles that persisted even in the booming 1980s.

I hope the covid-19 experience will be similarly formative for our generation, because going back to business as usual could condemn us to be the last. ▮

Graham's week

What I'm reading

I've gone back to one of my favourite novels, Galapagos *by Kurt Vonnegut, inspired by evolution and featuring a deadly new virus*

What I'm watching

O.J.: Made in America, *a magnificent five-part documentary series about the life of O.J. Simpson*

What I'm working on

Covid-19 stories...

This column appears monthly. Up next week: Annalee Newitz

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Editor's pick

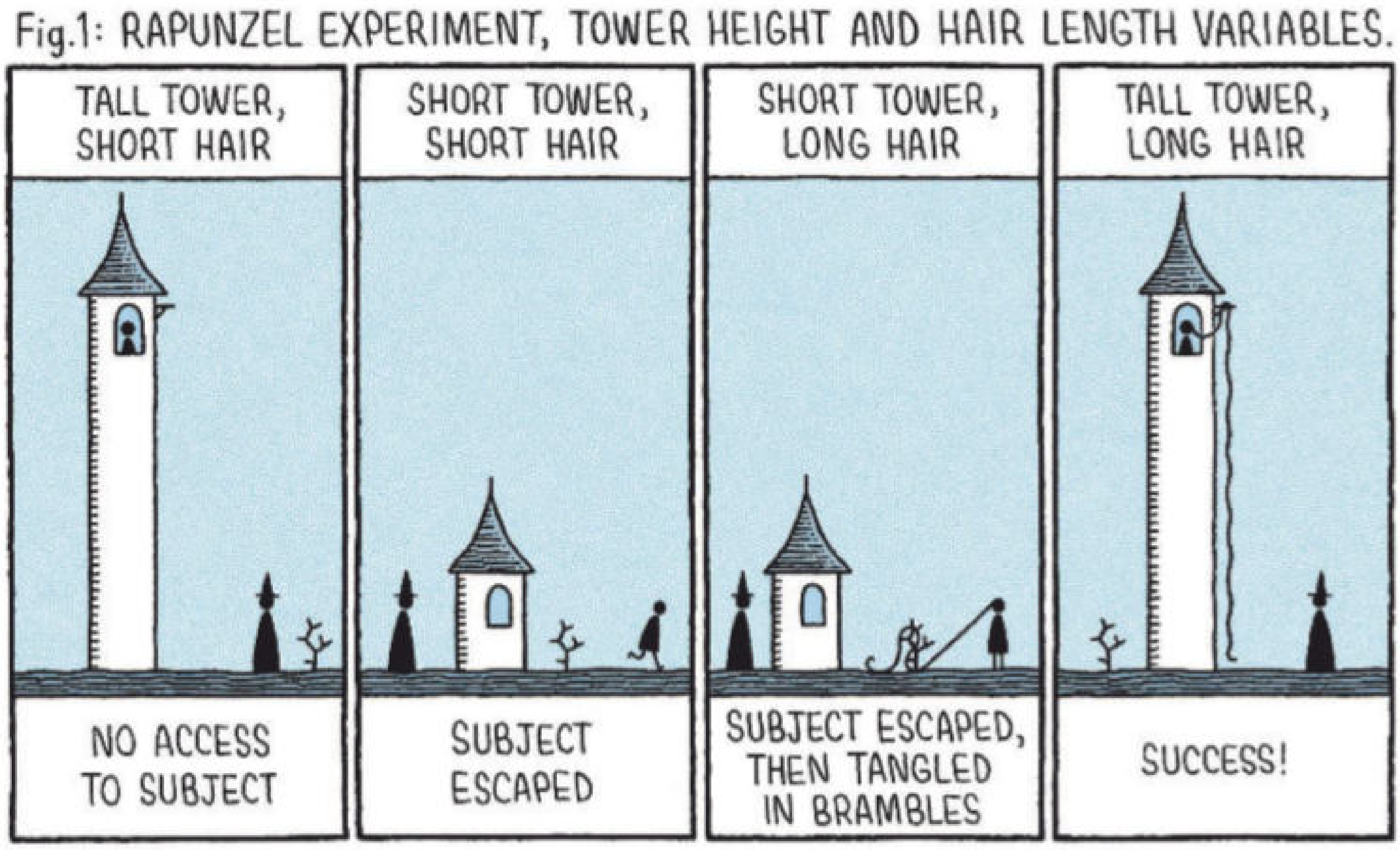
Here's hoping for some silver linings to covid-19

Letters, 11 April

From Roger Taylor,
Meols, Wirral, UK

I have spent many years watching politicians bring ignorance, stupidity and self-interest to issues. That said, I have to agree with Bryn Glover that some of them deserve applause for their efforts in dealing with the coronavirus. I won't be criticising their shortcomings on this given they've inherited a nightmare and they're stepping away from their old ways to deal with it.

I will, however, be speaking out for full advantage to be taken of the good things that can come out of the crisis: more rational governance, accelerated medical research, cooperation between multinational drug companies, procedures for dealing with such events should they happen again and, not least, open minds to listen to whatever comes out of us all reviewing our lives.



TOM GAULD for NEW SCIENTIST

How to escape from the lockdown

11 April, p 10

From Peter Sutton,
Guildford, Surrey, UK

Graham Lawton outlines three distinct options for navigating our way to a safer future: hold the lockdown restrictions for an extended period to see off the virus; build medical capacity to cope with a second wave and then ease the lockdown; or end the lockdown more rapidly but shield the vulnerable.

Surely a better strategy would be to integrate all three. This could allow the best options to be taken as and when they are most appropriate.

The UK must also include more stringent travel restrictions, like those in Australia. It is clear that the regions with the biggest airports and passenger numbers (US and Europe) have the most covid-19 cases, whereas Africa and South America, which have no airports among the world's 50 busiest, have the fewest.

Is air con a risk in the spread of the virus?

4 April, p 8

From Alan Harding, London, UK

You reported on the question of whether warmer spring conditions could slow the virus's rate of spread. Have any of the studies into the effects of temperature and humidity on the transmission of covid-19 taken air conditioning into account?

The use of air conditioning is widespread in most wealthy countries that experience very hot summers, such as Singapore and Australia. Hence many people in such nations spend a significant amount of their time indoors in an artificially cool and dry environment, conditions in which the virus might be most stable.

Could this, in part, explain why the incidence of covid-19 appears to be lower in African countries, where large parts of the population cannot afford air conditioning? In northern Europe, and the UK in particular, domestic air conditioning is also comparatively rare. Should the advice be to turn down or turn off air conditioning as the weather warms up in Europe?

Deliberate infection to test possible vaccines

21 March, p 44

From Birger Johansson,
Umeå, Sweden

Carrie Arnold explains the long road to an effective and safe coronavirus vaccine. The creator of the rubella vaccine, Stanley Plotkin, has suggested one way to speed things up: we should bypass ordinary testing protocol and expose volunteers in vaccine trials to the coronavirus after they are given test inoculations in order to check the efficacy of potential vaccines.

This idea was met with mixed responses. But with so many lives at stake, surely such a moonshot effort is worth it.

If we set aside ventilators and other critical care equipment for such volunteers, we may be able to reduce the risk to an acceptable level and find an effective vaccine more rapidly.

Australia's success seems to suggest sun is a help

18 April, p 10

From Diana George,
Cambridge, UK

You investigate why Australia has relatively few serious cases of covid-19. One factor could be that, at the end of summer in an outdoor living nation, few people will be deficient in vitamin D.

By contrast, in the northern hemisphere, other than in the tropics, people's vitamin D levels are now likely to be low.

Deficiency is known to raise the risk of respiratory tract infections. If this is a significant factor in covid-19, then discouraging people from being outdoors at a time when the sun is strong enough to generate vitamin D is one of the worst things you can do.

Big pharma's taxes do fund public research

Letters, 4 April

From Simon Goodman,
Griesheim, Germany

Sam Edge is certainly right when he says that pharmaceutical firms only bear a small part of the costs of vaccine development, as "most of their work is founded on existing research…". That is the way science works. Even Isaac Newton noted that he had seen further only because he could stand on the shoulders of others.

Edge suggests that drugs companies "pay little or nothing" to support that research. But they are, in fact, very significant taxpayers and so help support government finance of independent research in academic and healthcare organisations.

Parakeets may have invaded with Romans

11 April, p 42

From Ralph Hancock, London, UK

Thanks for an interesting article on the green parakeets that have invaded London.

Ring-necked parakeets have been brought to the West for a long time, no doubt along the Silk Road that has been in existence for thousands of years.

The Pergamon Museum in Berlin has a mosaic of one dating from the 2nd century BC. It has been misidentified as an Alexandrine parakeet and heavily and inaccurately restored, with an all-red bill (the bird has a black lower mandible) and red feet (the bird has beige feet), but the narrow red and black ring around its neck is from the original mosaic and clearly identify it as a male ring-necked parakeet.

They have probably been in Britain for more than 1900 years, brought by the Romans. In 2016, excavations in London found a wall painting dating from the 1st century AD, part of which shows an unmistakable pair of green parakeets.

From David Hambling, London, UK

Graham Lawton's "Little green alien invaders" don't always have an easy time. In our part of south London, the local peregrine falcons have expanded their usual menu of feral pigeon and now also take parakeets. As parakeets multiply, they may find themselves making up an increasing proportion of the peregrines' diet.

From Sandy Henderson, Dunblane, Stirling, UK

Perhaps one of the reasons we are so loath to take vigorous lethal action against invasive parakeets is that they remind us of ourselves.

Are we not the ultimate invasive species? Modern humanity likes to live in crowds, is very noisy, wastes a huge amount of food and displaces or renders extinct quite a lot of other species. The only thing going for the parakeets is that they are good-looking.

On what we want from the rise of the machines

4 April, p 32

From Sam Edge, Ringwood, Hampshire, UK

Regarding your review of sci-fi novel *Providence*, which is centred on the rise of powerful artificial intelligence: isn't what we are striving for in our AI omniscience rather than omnipotence?

Only if said entity were to have agency might it be omnipotent as a result, but this is by no means logically inevitable.

Perhaps we conquered the world just like monkeys

18 April, p 19

From Bruce Denness, Niton, Isle of Wight, UK

You reported on research suggesting that monkeys travelled on driftwood rafts from Africa to South America 35 to 32 million years ago. The east Atlantic Benguela current would have helped take them to the Amazon when sea level was lower because water was locked up in Antarctic ice.

Perhaps people accomplished a similar feat from Polynesia to South America about 20,000 years ago when ice began to melt at the end of the last glacial maximum, causing sea level to rise rapidly and inundate low-lying islands.

Inhabitants would have been left with little alternative but to cast their fate to the ocean currents and travel on them to New Zealand and then on the eastward-flowing Antarctic current to Chile.

Conventional wisdom has it that people reached the Americas from north-east Asia via a land bridge to Alaska and then spread southwards.

Surely the incentive for Polynesian islanders to avoid drowning would have been greater than that for Asian people to hike across barren, frozen wastes. The chronological order of archaeological sites throughout the Americas also suggests that people spread from the south.

Walking wins, as you can multitask while strolling

14 March, p 34

From Mike Vandeman, San Ramon, California, US

Steve Haake looked at the merits of running over walking. One factor wasn't considered: you can save time by reading while walking. Thus walking can't be accused of wasting your time, the way running can.

Variety may be the secret to successful dieting

11 April, p 18

From Eric Kvaalen, Les Essarts-le-Roi, France

You report on a study testing various popular diets, which found that they all led to weight loss and improvements in cholesterol in the first six months, although the effects disappeared later on.

Perhaps the explanation is that the gut biome isn't used to the new diet and somehow this causes weight loss and so on. But then, after six months, the biome adapts, and things go back to the way they were. So the solution is to change diets every six months. There's plenty of choice!

Are we really off the hook over bear's extinction?

11 April, p 18

From Dudley Miles, London, UK

You report on a new study suggesting that cave bears died out at the height of the last glacial maximum 24,000 years ago because their skulls were shaped in a way that prevented them from switching to a diet of meat.

Like many similar ideas, this doesn't explain why the bears were able to survive the equally severe glacial maximum about 140,000 years ago.

The difference is that modern humans hadn't reached Europe at the time of the earlier glaciation. Is this another case of special pleading to let humans off the hook for causing extinctions of large mammals?

A classic take on life in the deep blue sea

18 April, p 40

From Bob Ladd, Edinburgh, UK

Alert readers of "Creatures of the abyss" may have wondered about the names *Osedax* (said to mean "bone-eating" in Latin) and *Xylophaga* (said to mean "wood-eaters" in Latin).

They seem to have nothing in common, so which bit means "eat"? The explanation for the conundrum is simple: *Osedax* is based on Latin and *Xylophaga* on Greek. ▌

For the record

▌ Exoplanet TOI-849b has a surface area that is about 12 times that of Earth (18 April, p 14).

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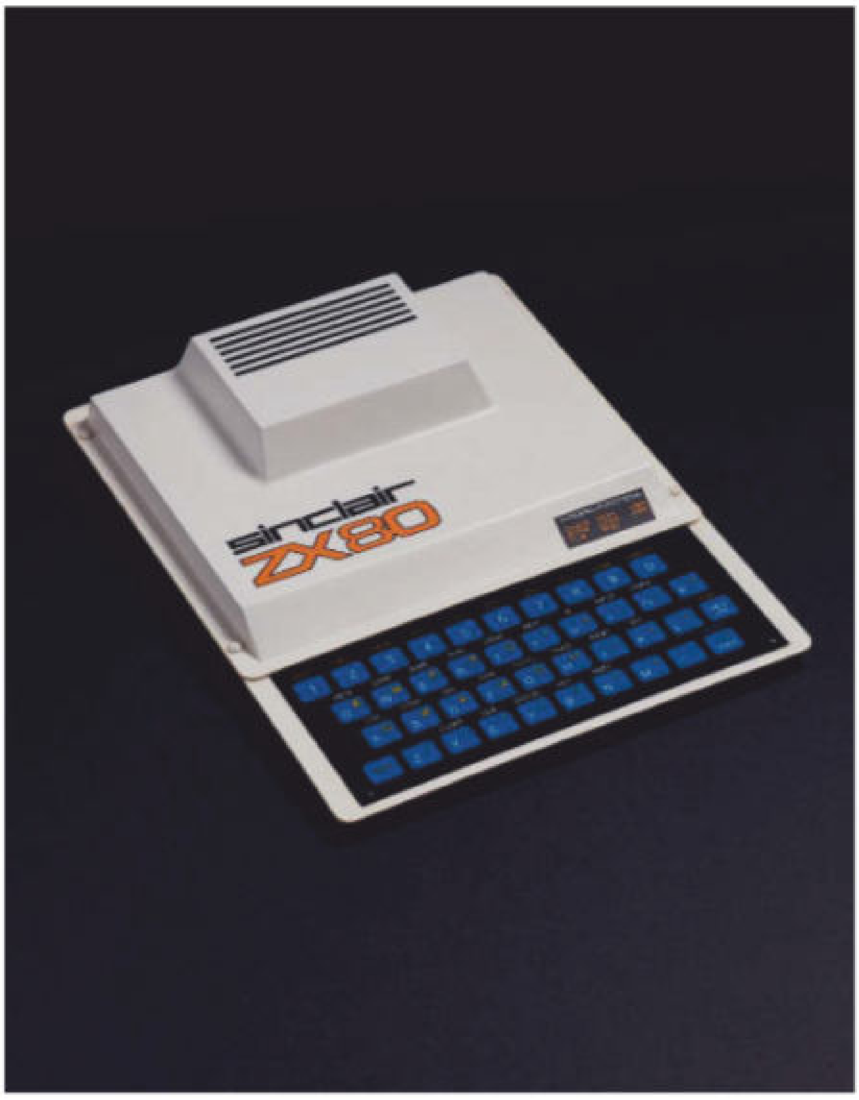
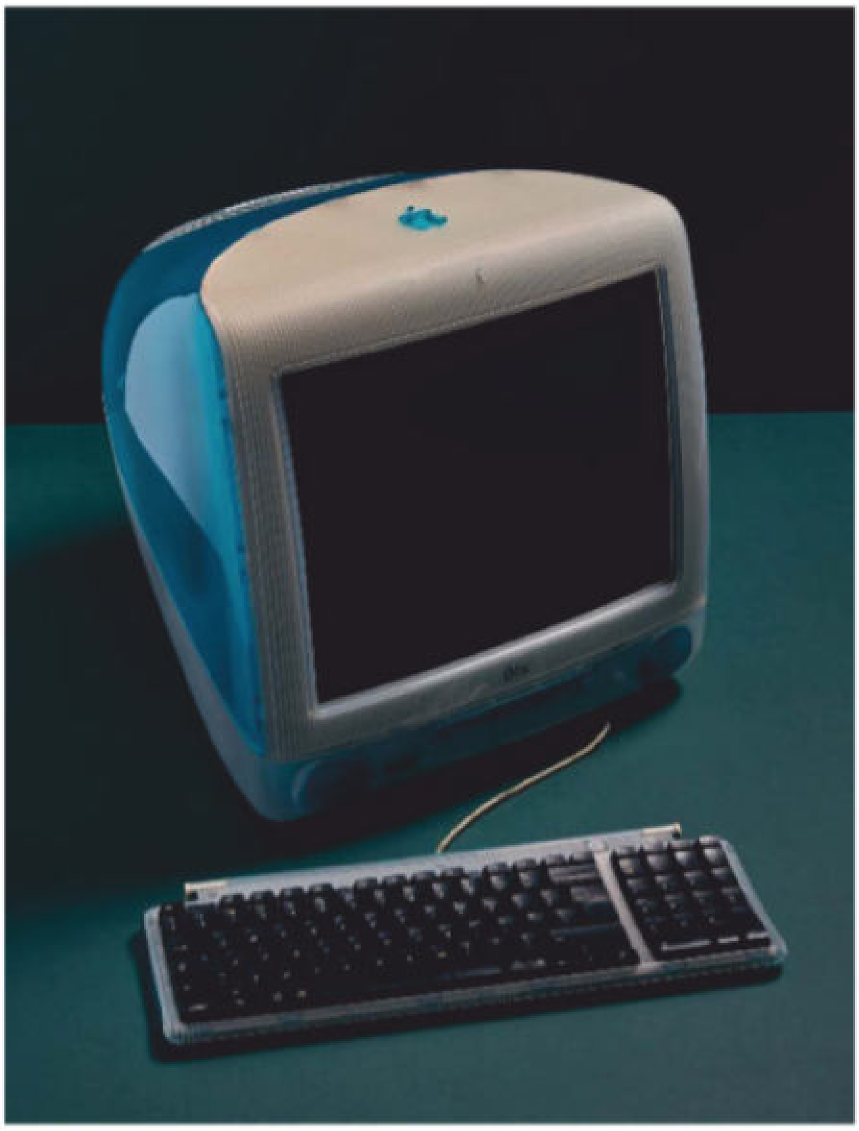




ALL IMAGES BY JOHN SHORT AND COURTESY OF THAMES & HUDSON

Pioneering PCs

Photographer John Short

THESE images of retro personal computers are a throwback to their humble beginnings, revealing the technological evolution of the devices over their first 25 years.

Taken by photographer John Short, these nostalgic shots feature in *Home Computers: 100 icons that defined a digital generation*, a new book by writer Alex Wiltshire. The computing compendium includes more than 400 images that capture details of past machines and prototypes, along with the ideas and influences behind them.

Personal computers began appearing in people's homes in 1975, and many different models soon emerged, including Commodore's PET 2001 in 1977 (bottom, far left) and the Intertec Superbrain (centre) in 1979.

The Sinclair ZX80 (top, near left) was one of the first affordable computers available in the UK, costing just £99.95 when it was launched in 1980 – the equivalent of around £430 today. Apple's original Macintosh computer (top, far left) was released in 1984 and was the first mass-market model to feature a graphical user interface, built-in screen and mouse. The range has gone on to become the brand's most popular and successful computers.

Apple's iMac G3 (bottom, near left), the most modern of this selection, was sold from 1998 to 2003 and was known for its bright and colourful plastic casing. ■

Gege Li

Remaining hopeful

Jane Goodall has tirelessly fought for a better world for humans and wildlife, and with covid-19 she says there are reasons to stay positive, finds **Donna Lu**

Film

Jane Goodall: The Hope
National Geographic

NATIONAL GEOGRAPHIC/BILL WALLAUER

Jane Goodall has campaigned to protect chimpanzees in the wild

> **"The kind of life I'm living is completely crazy and there are times when I think I cannot go on like this"**

NATIONAL GEOGRAPHIC/MICHAEL HAERTLEIN

JANE GOODALL has achieved an incredible amount in her life. As a researcher, she has changed our understanding of chimpanzees – highly intelligent animals with unique cultures and tight family bonds. As a conservationist, she has galvanised generations of activists.

A new documentary, *Jane Goodall: The Hope*, features footage spanning more than seven decades, including her early chimpanzee work at Gombe Stream National Park in Tanzania. The film picks up where the 2017 documentary *Jane* ended, focusing more on Goodall's shift to environmental activism.

"We are part of the natural world," she says in the film. "As we destroy the natural world we destroy our own future."

Before the covid-19 pandemic shut borders, Goodall was travelling 300 days of the year, giving talks to packed theatres and meeting thousands of school children through her youth programme, Roots & Shoots, which runs in more than 60 countries. "The kind of life I'm living now is completely crazy and there are times when I think I cannot go on like this," she says.

We see Goodall in her home in Bournemouth in the UK, toasting bread on an iron in a hotel room, and working on her laptop while sitting on the ground in an airport. She seems propelled by an urgent sense that time is running out.

"I think this pandemic is waking people up," Goodall told me during a press call. The impact of environmental destruction has been brought into focus by the covid-19 outbreak, she says, as a result of practices that bring different species into closer proximity with each other, creating opportunities for viruses to jump from animals to humans.

Great apes are known to be susceptible to human respiratory illnesses. In her sanctuaries for orphaned chimps, staff are wearing protective gear as a precaution against covid-19.

"We've stopped actually following the chimps in our studies," she says on the call. "We just have one person a day in protective masks and gloves… not going near the chimps, just from a distance monitoring them to see if there is any sign of disease, and hopefully not coming across dead bodies.

"It is a big worry because we can't protect all the chimps across Africa and once the virus gets into them, which I pray it won't, then I don't know what can be done."

But despite the current state of the world, she remains hopeful. "Nature is so resilient. We see that now that the pollution from driving and so on has stopped [due to lockdowns across the world], the air in the big cities is clean," she says on the press call.

"That's another hope: that enough people will suddenly realise what it could be like without the pollution, and that there'd be enough of them to persuade their politicians to make legislation to stop the pollution coming back."

It may be an era of climate emergency and overwhelmingly negative news, but for Goodall, despair is simply not an option. "If we lose hope, then we might as well all give up," she says while giving a lecture in the film. "If we think there's no way forward and that we're doomed, as many scientists tell us, then eat, drink and be merry, for tomorrow we're going to die." The audience laughs, but she presses on. "We mustn't let it happen."

"Wherever I go, there are young people with shining eyes wanting to tell Dr Jane what they're doing to make this a better world," she says on the press call. "They're… influencing their parents and grandparents. Some of their parents may be in government; some of them may be in big corporations."

Her message, one *The Hope* conveys clearly, is of the promise of collective action.

"Hope is contingent upon our taking action together soon," she tells an audience in the film. "All of us, every single one of us, we've all got to do our bit." ▮

Always the end of days

People have been preparing for the apocalypse since the dawn of time, but some more seriously than others, says **Alex Diggins**

Book

Notes from an Apocalypse: A personal journey to the end of the world and back

Mark O'Connell

Granta

HUMANITY has always had half an eye on the end of the world. In fact, as Mark O'Connell writes in his entertaining new book, some sort of apocalyptic expectation seems to be a precondition of being human.

Saint Augustine, for instance, wrote in the 5th century that early followers of Jesus fervently believed themselves to be living in the end of days. Augustine thought they were jumping the gun by a few centuries though, lamenting that: "If there were 'last days' then, how much more so now." It has always been the end of the world for someone, somewhere, writes O'Connell.

Notes from an Apocalypse is an exhilarating romp through the end times, an exploration of doomsday preparation from Mars colonists to fallout shelter estate agents. O'Connell is fascinated by the ageless human fear of the future, but his book also speaks very particularly to our present moment.

In his travels, he investigates Silicon Valley billionaires buying up swathes of New Zealand as a "kind of reinforced geopolitical shelter", a country-sized insurance plan. New Zealand is remote and blessed by abundant clean water and plenty of space.

However, more than that, O'Connell argues, it offers these techno-libertarians, such as the data analytics mogul Peter Thiel, a chance to play out their political fantasies. Not only can they weather the apocalypse from their lavish retreats but, once it is all over, they can attempt to rebuild the society they long for.

The book also follows the more DIY forms of preparation. O'Connell plunges into the "prepper" internet subculture, a phenomenon whereby people – primarily white men in the US – amass vast quantities of survival equipment and devise complex escape plans for when things go wrong.

Working out exactly when that has happened is among the drawbacks of this apocalypse game plan, O'Connell concludes. For example, should the covid-19 pandemic make you head for the hills? As a movement, he writes, it is evangelical in its anti-scientism, fuelled equally by freeze-dried foodstuffs and unpalatable politics.

Notes from an Apocalypse explains how planning for the future, however horrid, is a luxury few can afford. For many, surviving the here and now is a sufficient trial. After all, even those fortunate enough to be cushioned by functioning government and healthcare have felt the strictures of living through a global pandemic.

O'Connell's previous book, *To Be a Machine*, was a gloriously gonzo study of transhumanism – the idea that we might exceed our bodily limits and lifespans via technology. It was thoughtful, and very funny.

Notes from an Apocalypse is just as spirited. Reflecting on Elon Musk launching a Tesla into solar orbit, he writes: "I wondered why no one at SpaceX had thought to point out to Musk that he could have ensured his red sports car would orbit the sun indefinitely by leaving it parked in front of his house."

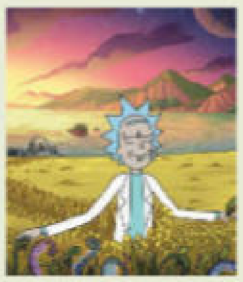
In the closing pages, O'Connell turns to watching his children's joyous appreciation of the world. "There are times when I forget I'm supposed to be thinking about the end of days," he writes. "There are times when I live only in the present, and it is a good place for the time being." ▮

Alex Diggins is a freelance writer based in London

Billionaires are building bunkers in New Zealand to hide from the apocalypse

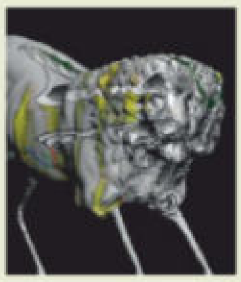
AYAX/GETTY IMAGES

Don't miss



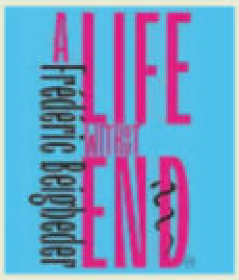
Watch

Rick and Morty returns on 3 May on Netflix. Filled with genuine science references, anxiety prone Morty Smith and his mad scientist grandpa Rick Sanchez (pictured) go on animated adventures across the universe**.**



Visit

Platform is a five-week programme showing art in the making by the Delfina Foundation, available via its website delfinafoundation.com. Digital sculptures from Petros Moris's Future Bestiary are first up.



A LIFE WITHOUT END

Frédéric Beigbeder

Read

A Life Without End describes French literary critic and TV host Frédéric Beigbeder's brutally funny attempts to talk, write and research his way out of his own death. It is sharply translated by Frank Wynne.

NETFLIX; PETROS MORIS

The sci-fi column

Through the eyes of a robot *Network Effect* is a glorious, pulpy, action-packed book about a Murderbot, and it raises fascinating questions you will think about long after you have finished it, says **Sally Adee**

Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee

Book

Network Effect

Martha Wells

Tor.com

JAIME JONES

In *Network Effect*, Murderbots work in a high-tech world

BEFORE writing begins, most fiction authors must commit to a basic choice. Through whose eyes will readers inhabit this story and what is their gender?

That presents an immediate problem. Choose male and you risk alienating female readers and vice versa. The choice isn't the same each way, though: evidence suggests that women have an easier time looking at the world through the eyes of a character of a different gender than men do.

You could agonise over this decision, or you could be Martha Wells and sidestep the whole mess by making your protagonist a gender-irrelevant security robot.

The Murderbot is a hybrid security robot manufactured by a sci-fi staple megacorporation. It is made from weaponised robot parts, driven by a human brain and threaded through with human nerve tissue. It has pain sensors to motivate it to minimise damage to itself, and its brain provides limited agency to execute decisions and react fast without commands from afar. But the limitations on its agency are fundamental. Every Murderbot has an implant called a central governor that will flash-fry its brain if it disobeys too many commands or displays interest in making its own decisions.

Before we meet the Murderbot in Wells's new novel, *Network Effect*, it has found a way to disable its governor module, and it is now faced with the big question we all grapple with. You have free will, what are you going to do with it?

> **"Anecdotal evidence suggests that women experience the robot as female, while men think of it as male"**

From there all the action flows, in a pulpy, action-packed book that could be described as part *My So-Called Life* and part *Terminator*. When the Murderbot isn't dispatching baddies, it is finding creative ways to evade social interactions so it can focus on bingeing box sets, possibly its way of processing the trauma of having been forced for years to be a killing machine. The word "robot" disguises many sins, but it is worth remembering its origins: the Czech word *robota*, meaning "forced labour". The book finds the robot accompanying a planetary survey crew, which is kidnapped under mysterious circumstances by beings that may have killed Murderbot's best and only friend. How can she get out of this alive?

Ah… "she". That's the funny thing about the Murderbot. Its absolute lack of gender identifying characteristics quickly lock you into its perspective so fast that the difference between reader and Murderbot disappears.

I have no published data on this, but anecdotal evidence suggests that women experience the Murderbot as strongly female, while men think of it as male. Here we have a genderless brain in a genderless robot body that it is very easy for the reader to inhabit. The Murderbot may be the ultimate human protagonist. What does that imply about the way we view gender?

Beneath the fun romp lurk complicated questions. What is the difference, for example, between a robot with human tissue and a human with robot parts? Why is one owned by a corporation and the other a free agent? Who decides the level of humanity you are endowed with?

Wells doesn't linger on such questions long enough to let them bog down the action. But you are left thinking about them long after you finish the book. Which, by the way, is too soon.

As we may be stuck in social isolation for the foreseeable future, I can think of no better company than this paranoid android. ▮

Sally also recommends…

Book

Murderbot series

Martha Wells

Tor.com

My one recommendation is that you should read the Murderbot series in order. Although it isn't necessary, it will make the overarching plot more gripping, the characters more realised and the resolution sweeter. All Systems Red *is the first in the series.*

New Scientist events

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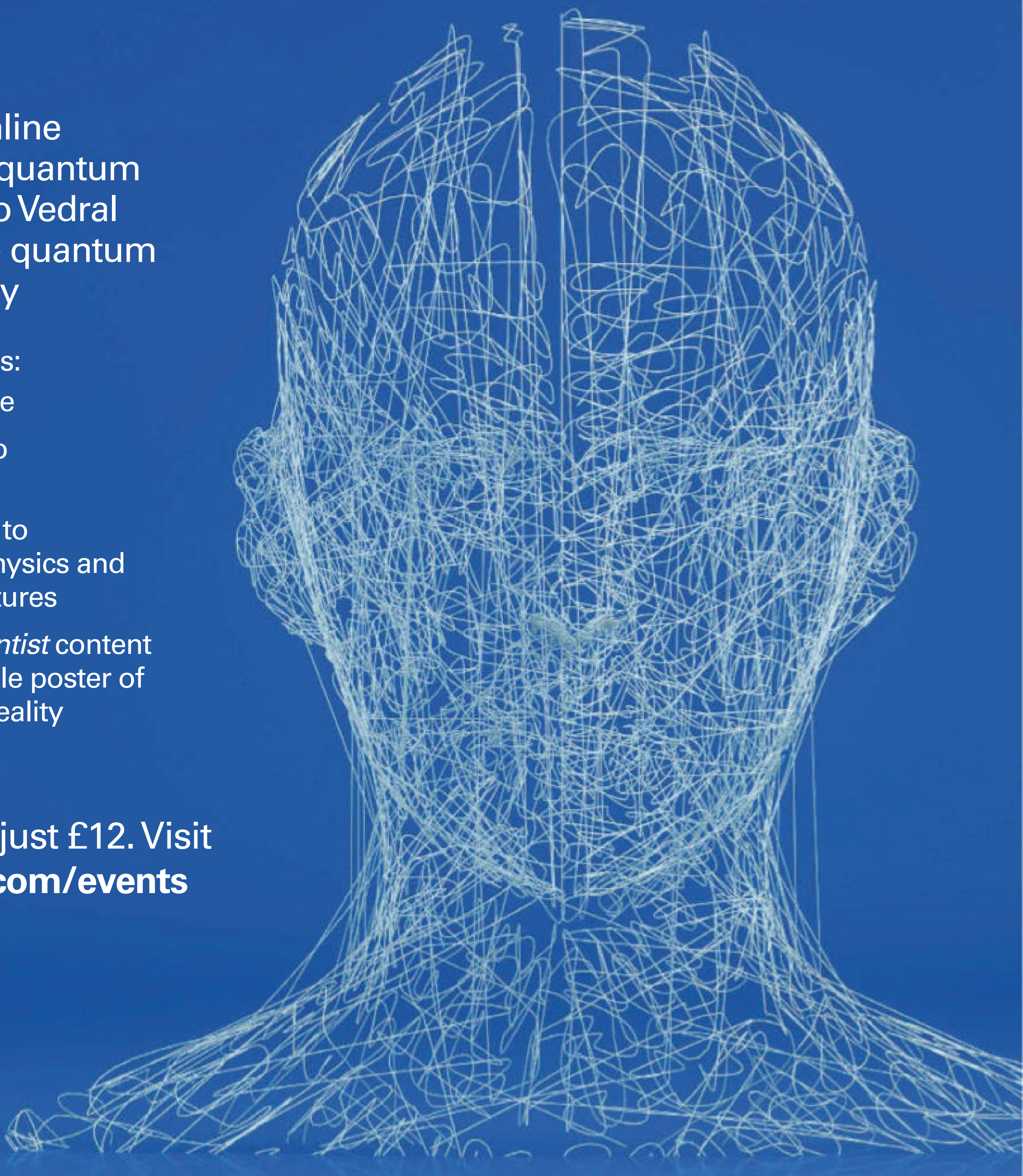
Vlatko Vedral, University of Oxford



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OC43
S
NL63

An uncommon cold

The covid-19 virus isn't the first coronavirus to jump from animals to humans. What can we learn from previous encounters, asks **Anthony King**

IN 1889, a disease outbreak in central Asia went global, igniting a pandemic that burned into the following year. It caused fever and fatigue, and killed an estimated 1 million people. The disease is generally blamed on influenza, and was dubbed "Russian flu". But with no tissue samples to check for the flu virus, there is no conclusive proof.

Another possibility is that this "flu" was actually a coronavirus pandemic. The finger has been pointed at a virus first isolated in the 1960s, though today it causes nothing more serious than a common cold. In fact, there are four coronaviruses responsible for an estimated 20 to 30 per cent of colds. Only recently have virologists begun to dig into these seemingly humdrum pathogens and what they have found suggests the viruses have a far more deadly past. Researchers now believe that all four of these viruses began to infect humans in the past few centuries and, when they did, they probably sparked pandemics.

The parallels with our current crisis are obvious. And it turns out that our growing knowledge about these other coronaviruses could be vital in meeting the challenge of covid-19. Insights into the origins, trajectories and features of common cold coronaviruses can provide crucial clues about what to expect in the coming months and years. Understanding these relatively benign viruses may also help us avoid another pandemic.

Coronaviruses are a big family of viruses that are mainly known for causing diseases in livestock. Until recently, few virologists paid them much attention. "Human coronaviruses were recognised in the 1960s," says Frank Esper at the Cleveland Clinic in Ohio. But the two strains that were discovered then merely caused the common cold. "We pushed them to the side," he says. "We had more important viruses to work on."

This blasé attitude evaporated in 2002 when a new member of the coronavirus family began infecting humans. By the time the epidemic of severe acute respiratory syndrome (SARS) was brought under control the following year, the SARS-CoV-1 virus had affected 26 countries and killed one in 10 of the 8000 plus people it infected. The fact that a coronavirus could be so deadly was a wake-up call. A sleepy backwater in the world of virology was suddenly in the spotlight.

SARS-CoV-1 was soon traced back to its roots. Related viruses were discovered in bats, animals whose unusual physiology allows them to live with a cornucopia of coronaviruses without falling ill. The SARS outbreak seems to have been sparked when one of these bat viruses started infecting civet cats, and moved from this intermediate host to humans.

Coronaviruses have proteins on their surface, which act like a key that unlocks different cells in different host species. These proteins can shape-shift as a result of genetic mutations, or when the viruses swap genetic material with one another, opening new doors to new hosts. That these hosts might be humans was made worryingly clear by the SARS outbreak. Caught off guard, virologists embarked on a coronavirus safari, tracking them down in people and wildlife in an attempt to understand how these changes might happen and the potential future risks.

"An estimated 20 to 30 per cent of common colds are caused by four coronaviruses"

One virus hunter was already ahead of the game. Lia van der Hoek at the University of Amsterdam in the Netherlands had been perfecting a genetic technique to discover unknown viruses and had recently found another coronavirus, HCoV-NL63, in a 7-month-old child with bronchiolitis. "I found NL63 by accident, before we knew about SARS, and the whole world starting screening," she says. A decade of subsequent research revealed that NL63 is widespread, turning up in between 1 and 9 per cent of people with respiratory tract infections around the world. It causes fever, coughs, sore throats, bronchitis and pneumonia. Children are invariably infected with it in the first years of life. "The loud cough that children can get, like barking seals, that is typical of NL63," says van der Hoek. In other words, NL63 is another coronavirus associated with the common cold.

Relatives of NL63 have since been found in pigs, cats and bats. In 2012, genetic comparisons between the human virus and those found in bats indicated that they shared a common ancestor between 563 and 822 years ago. This suggests that the virus made the leap to humans sometime in the 13th to 15th century. When it did, the result was probably a pandemic, says virologist Ralph Baric at the University of North Carolina. Like SARS-CoV-2, the virus that causes covid-19, the original NL63 would have been deadly in a human population lacking any immunity. Both viruses latch on to the same cell receptor, angiotensin-converting enzyme 2, which is plentiful in the lungs and intestines. "This would look like a flu-like disease," says Baric. ›

ISRAEL G. VARGAS

What causes the common cold?

The average adult has two or three colds a year, and children have more. These are caused by a gang of viruses, including four coronaviruses (see main story) that account for around a quarter of all such infections.

Most often, however, the culprit is a rhinovirus, literally "nose virus". There are about 100 different types, that are together responsible for half of all colds. As well as the usual coughs and sniffles, rhinoviruses have been linked to ear and sinus infections.

Two other related viruses, respiratory syncytial virus and human metapneumovirus, home in on the respiratory tract. In severe cases, they can cause pneumonia and bronchitis.

If you contract a summer cold, the likely perpetrator is human parainfluenza, which comes in four varieties. These sometimes lead to serious illness too. Nevertheless, as with most colds, the usual outcome is that you will recover in a week or so.

"But one that caused more severe disease in the elderly compared to the young."

Baric would like medical historians to search for evidence of a medieval pandemic, but there is no guarantee they would find any. Back then, people experienced myriad infections, including viruses like flu and bacterial diseases like tuberculosis, says van der Hoek. "I'm not sure a SARS pandemic in the Middle Ages would even be noticed," she says. However, it is possible that such evidence exists for another, more recent, human coronavirus pandemic. This is where Russian flu enters the story.

Rethinking Russian flu

Following the SARS outbreak, there was renewed interest in the two seemingly unexciting common cold coronaviruses discovered in the 1960s, HCoV-229E and HCoV-OC43. "These viruses don't have fancy names, which means they have not been studied very much," says Marc Van Ranst at KU Leuven in Belgium. "OC43 and 229E were orphan viruses for a long time." In 2003, he and his team became the first to sequence the genome of OC43, which was discovered in 1967 at the Common Cold Unit in Salisbury, UK. By comparing its sequence with strains found in other animals, the researchers concluded that OC43 must have originated in cattle or pigs. Accounting for expected mutation rates and working backwards, they calculated that the jump into humans occurred around 1890. Sound familiar?

That date isn't the only thing linking OC43 with Russian flu. Many patients of that pandemic had pronounced symptoms affecting their central nervous system. Today, although mostly associated with mild colds, OC43 is also known to infect nervous tissue. It is a suspect in nervous system conditions such as chronic demyelinating disease and multiple sclerosis. What's more, a 1994 report of a 6-year-old child contracting a bovine coronavirus suggests cattle strains can indeed sneak into people. If OC43 was the culprit in the 1889/90 pandemic, it has clearly lost its sting in the past 130 years. "It probably lasted a fair number of years, like bad flu seasons, until it slowly lost pathogenesis," says Van Ranst.

What about 229E? First isolated in the mid-1960s, subsequent experiments indicated that half of volunteers infected with 229E fell ill with a cold after two to five days. In 2007, it stepped back into the limelight when a close relative was discovered in the lungs of alpacas with respiratory disease. Meanwhile, researchers led by Christian Drosten, then at the University of Bonn in Germany, had been investigating an array of 229E-related coronaviruses from leaf-nosed bats in Ghana. Their studies indicated that 229E left bats on its path to people some time between 1686 and 1800.

The pieces of the puzzle started to fit together in 2012 when a mysterious and deadly new coronavirus first struck in Saudi Arabia, causing what was named Middle East respiratory syndrome (MERS). The virus responsible, MERS-CoV, was traced back to dromedary camels and, while digging into this link, Drosten and others discovered that 5.6 per cent of these camels in Arabia and Africa are infected with viruses akin to 229E.

Genetic comparisons of 229E and related viruses in animals suggest that it originated in African bats and moved to camels, before infecting people in or around the late 18th century. Like MERS, it probably sparked a pandemic when it arrived in humans as they would have had no immunity to it. As with NL63, nobody has looked for evidence in historical records.

The idea that common cold coronaviruses were far more deadly when they first appeared in humans is supported by animal studies. In 2016, for example, scientists caught a coronavirus in the act of jumping species into pigs. "The genetic sequence was closely related to coronaviruses in bats, so it looked like the virus had spilled over directly from bats," says Linda Saif at Ohio State University. That virus killed 25,000 piglets in China in just a few

A 19th-century flu pandemic may have been caused by a coronavirus

TOUT LE MONDE L'A L'INFLUENZA!
ANTI
La Ronde des Médecins et des Potards.

ARCHIVES CHARMET/BRIDGEMAN IMAGES

months. Such events are common, says Saif, who has been investigating new coronavirus outbreaks in animals for decades. In the 1990s, for instance, a respiratory coronavirus devastated cattle herds with “shipping fever”. And in 1977, a diarrhoeal disease caused by a coronavirus emerged in pigs in Europe, later spreading to China and then the US, where it killed an estimated 8 million pigs.

“It is quite possible that when these [common cold] coronaviruses first jumped over to humans, they would have caused episodes of severe disease,” says Saif. What is surprising, however, is how infrequently such leaps seem to have occurred. “When SARS happened,” says Esper, “people like myself started looking for other coronaviruses that might cause respiratory infections.” Only one new one turned up. In 2005, the fourth common cold coronavirus was discovered in a 71-year-old pneumonia patient in a Hong Kong hospital. HCoV-HKU1 causes respiratory illnesses and has been recorded worldwide. Its closest relative appears to be a rodent coronavirus. We don’t know when it began infecting humans. Esper points out, though, that people are less likely to be hospitalised with HKU1 and NL63 than with 229E and OC43, possibly indicating that the former pair have more ancient roots in human populations.

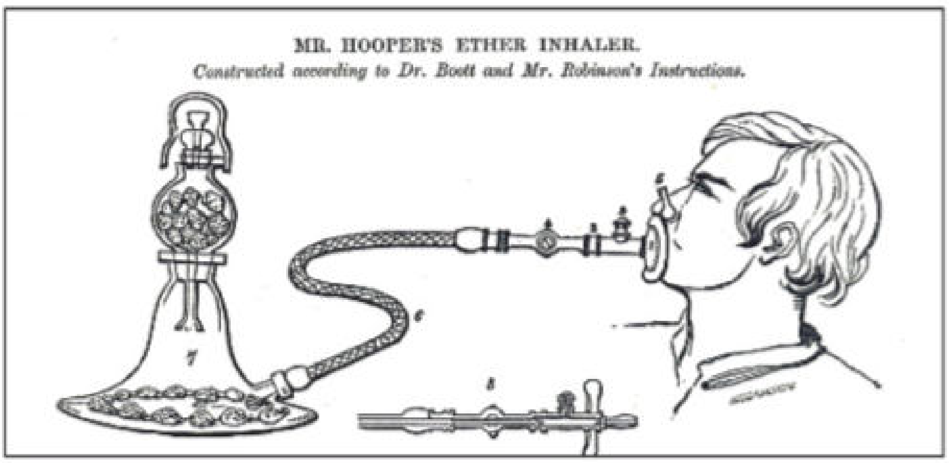
HKU1 attracts little attention, but Esper took a special interest in it when it was found in several patients in a local Ohio hospital. He discovered that older people are especially hard hit by this coronavirus. Indeed, while the common cold viruses are often thought of as childhood ills, Esper says his team has found that adults account for 70 per cent of infections by these coronaviruses. That is different from most viruses, but matches what we are discovering about the covid-19 virus. “All these coronaviruses seem to be acting very similarly,” says Esper. “Understanding why they infect adults so much may be one of the key questions that will give us an understanding of the current coronavirus pandemic, as well as future ones.”

Inter-viral competition

Our four common cold coronaviruses have another intriguing feature: they ebb and flow. “For NL63, you have high years and low years,” says van der Hoek. “We found it more or less peaks every two years.” In addition, between 2000 and 2010, NL63 and OC43 infections were more common in children than 229E and HKU1 infections. “They are in competition,” she says. Esper has also observed the viruses hitting in relays. “Here in Ohio, we just had a banner year for HKU1,” he says, with 160 confirmed cases. OC43 was also quite common, but there were almost no cases of NL63 or 229E. “Maybe it’s because our immune system revs up, gives protection for a couple of years, and then goes away,” he says.

MEDISCAN/ALAMY

People infected with Russian flu in 1889 may have found themselves on elegant hospital wards (above) with rudimentary treatments (right)


MR. HOOPER'S ETHER INHALER.
Constructed according to Dr. Boott and Mr. Robinson's Instructions.
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8

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But there could be something darker going on. One experiment done in 1990 found that volunteers infected with 229E were vulnerable to reinfection a year later. If that happened, they experienced no symptoms but could still pass on the virus. Van der Hoek thinks this has worrying implications for coping with covid-19. “Can you imagine what this means for protecting vulnerable people when we have even more asymptomatic people shedding the virus without knowing,” she says. People with antibodies to SARS-CoV-2 must be studied, she says, to see if the same is true for covid-19.

Nevertheless, research on our common cold viruses provides some grounds for optimism too. The coronavirus family tree consists of four subfamilies, with the human ones occupying two of these. NL63 and 229E are in a group called alpha, along with feline and canine coronaviruses. OC43 and HKU1 belong to the beta subfamily, which also includes the viruses that cause MERS, SARS and covid-19. Antibodies for one virus might be effective against a related one, says van der Hoek. “We should definitely investigate whether people have a little bit of protection already [to covid-19] when they have just experienced an OC43 or HKU1 infection,” she says. However, the reverse may be true, warns Van Ranst. “Maybe if you are older and have some residual immunity against some coronaviruses, there’s a greater chance that your body will overreact.”

In the longer term, virologists cannot predict how SARS-CoV-2 will evolve. It may continue to cause severe illnesses for some years yet, especially among older people. However, it seems likely that one day it will be just another common cold coronavirus. These are hit-and-run viruses, says Esper. “They infect you, make a million virus babies and spread them all out”, but our immune system usually kills them off within five days. If the viruses are too deadly, they won’t get a chance to spread, so it is in their interests to become more benign. “If SARS-CoV-2 persists, which I expect it will, it may get milder over time,” says Esper. ▮

Anthony King is a freelance science journalist based in Dublin, Ireland. He tweets occasionally at @antonyjking

How the turtle got its shell

Incredible fossils are helping solve one of evolution's most perplexing mysteries. **Riley Black** investigates

CONSIDER the floating fortress that is a sea turtle. It seems to fly gracefully through the water even though it is encased in heavy armour. This combination of poise and protection evolved like any wonder of the animal kingdom, yet until recently the fossils we had found made it seem as if they emerged fully formed hundreds of millions of years ago. In fact, scientists who study the evolution of these animals have a running joke: turtles might as well have come from space.

In the past few years, however, truly ancient fossils have been discovered and they are helping to unravel this real-life just-so story. As we uncover fresh clues, we are learning that the tale of how the turtle got its shell reads nothing like we had previously guessed.

In the UK, the word "turtle" usually refers to the reptiles that swim in the sea, but these are just one branch of a larger group that includes species that burrow in desert sand and slog through swamps. Whether we are talking about a Galapagos tortoise, green sea turtle or red-eared terrapin at the pet shop, they all belong to an order called Testudines – which zoologists tend to call the turtles or chelonians.

All living animals in this order are united by their shell and the modifications required to live inside this box of bone. Their upper ribs are fused to the inside of their shell and their shoulder joints are set inside their ribs. This anatomical form is unprecedented among vertebrates. Imagine how your arms would move – or rather wouldn't – if your shoulders

LEFT: DORLING KINDERSLEY LTD/ALAMY; RIGHT: DAVID FLEETHAM/NATURE PL

were inside your ribcage. "It is the shell and associated features, such as the position of the limb girdles inside it, that makes turtles so unusual," says palaeontologist Hans Sues at the Smithsonian National Museum of Natural History in Washington DC.

Less obvious but equally confusing are the holes in turtle skulls. Or rather the lack thereof. Look at the back of almost any other reptile skull – whether it is a gecko or a *Tyrannosaurus rex* – and you will see a pair of openings for jaw muscle attachments. Turtle skulls, with their toothless beaks, don't have these holes, making them an oddity that lacks a clear connection to any other group of reptiles.

These features stretch back into deep time. Around 13 million years ago, a turtle aptly known as *Stupendemys* grew as large as a small car. About 75 million years ago, lived *Archelon*, which at 4.6 metres from head to tail is the largest turtle ever documented. Yet these are youngsters compared with *Proganochelys*, the first specimen of which was found in roughly 220-million-year-old rock in Germany and named in 1887.

Spiky on top

For decades, *Proganochelys* stood as the most primitive turtle known. Yet it was unquestionably a turtle, from its spiky shell to the arrangement of its shoulders and lack of holes in the rear of its skull. This wasn't much help to those trying to figure out how turtles evolved. Researchers wanted to find the remains of a creature that was on its way to becoming a turtle, but the earliest examples looked fully formed and offered no clue to the appearance of a turtle ancestor.

"For well over a century, most zoologists could not even imagine what a proto-turtle would have looked like," says Sues. Eventually, some palaeontologists began to guess that they should look out for a fossil with blobs of bony armour on its back and abdomen, the first hint of a shell. Some called it the polka dot ancestor.

Things changed abruptly in 2008, when Chun Li at the Chinese Academy of Sciences in Beijing and his colleagues described a new fossil turtle that didn't look quite like any other. Named *Odontochelys*, the turtle was found in ancient ocean sediments in China that were about the same age as *Proganochelys*. Yet this fossil was a turtle

›

Hawksbill turtles swim in the sea, but look similar to tortoises (far left)

Real just-so stories

Fresh evidence from fossils and genomic analysis is teaching us how several strange wonders of the animal kingdom truly came about

How the whale lost its legs

It is thought that whales trace their lineage back to deer-like creatures that ventured into the water to feed many millions of years ago. At some point between then and now, whales lost their legs. As evolutionary transitions go, it is fairly extreme. Fossil discoveries over the past decades have begun to paint a picture of how it happened.

About 50 million years ago, early whales began to evolve from animals that swam by kicking both sets of legs, doggy-paddle style. Later forms had shorter legs with webbed hands and feet, a powerful tail and a long snout.

At first, keeping their legs gave these early whales the option of returning to land, perhaps for resting or breeding. But then whale ancestors began to swim by undulating their bodies, using their front proto-flippers to steer. At this point it seems their hind limbs got in the way of their tails. Those animals with the smallest hind limbs became the best swimmers, and the rest is history.

How the panda got its thumb

Humans are part of a select group of animals with an opposable thumb. We tend to forget that pandas are also members of the club – well, sort of. Next to the five toes on their front paws, they have a stubby modified wrist bone that they use like a thumb. Giant and red pandas both have it. But how come?

Genomic analysis recently identified two genes involved in limb development as candidates for explaining the origin of this pseudothumb. Mutations in the equivalent genes in humans and mice can disrupt skeleton formation. It looks like this is what happened to both species of panda independently, but the bone mutation turned out to be useful.

Both the red and giant panda feed on bamboo in a way that means dexterity is highly beneficial to them. Being able to select young shoots and strip out the tender core of stems means panda diets are about 50 per cent protein, despite them being vegetarian.

How the zebra got its stripes

Scientists have come up with many explanations for why zebras evolved stripes, ranging from camouflage to display signals to heat regulation. But over the past few years evidence has been quietly mounting for a different and unexpected possibility.

A 2019 study of captive zebras and horses in the UK revealed that fewer horseflies landed on zebras compared with horses. Horses that were dressed like zebras – wearing black and white striped cloth coats – also had fewer horseflies land on them, compared with horses wearing either black or white coats.

Why the stripes make it less likely that the flies will land isn't yet clear. Still, fake zebra stripes seem to protect other animals too. When Japanese black cows were painted with zebra-like stripes they were also less susceptible to biting flies. The authors of this study suggest that painting black-and-white stripes on livestock could be an alternative method of pest control.

This raises the question of why other animals didn't evolve stripes to ward off flies, too. It may be that selection pressures for avoiding biting flies were higher for zebras because in the region of Africa where they live, biting flies can transmit deadly disease-causing parasites.

Layal Liverpool

> **"When black cows were painted with stripes, they avoided attack from biting flies"**

REBECCA ELDRIDGE/GETTY IMAGES

in a half shell, a primitive animal protected on the abdomen but with no carapace on top. This hinted that turtles evolved their shells in piecemeal style, the bottom half first. *Odontochelys* had teeth, too – it was clearly a stage between turtles as we know them and their more ancient ancestors.

"This discovery released palaeontologists from their self-imposed search image for a proto-turtle with shells and instead focused the search to animals with broadened ribs," says Tyler Lyson at the Denver Museum of Nature and Science. The finds have been rapidly piling up since then. In 2015, Sues and his colleague Rainer Schoch named *Pappochelys*, a more ancient turtle with a lizard-like appearance. Three years later, Li described another turtle called *Eorhynchochelys* that had a lizard-like body but a toothless, beaked skull.

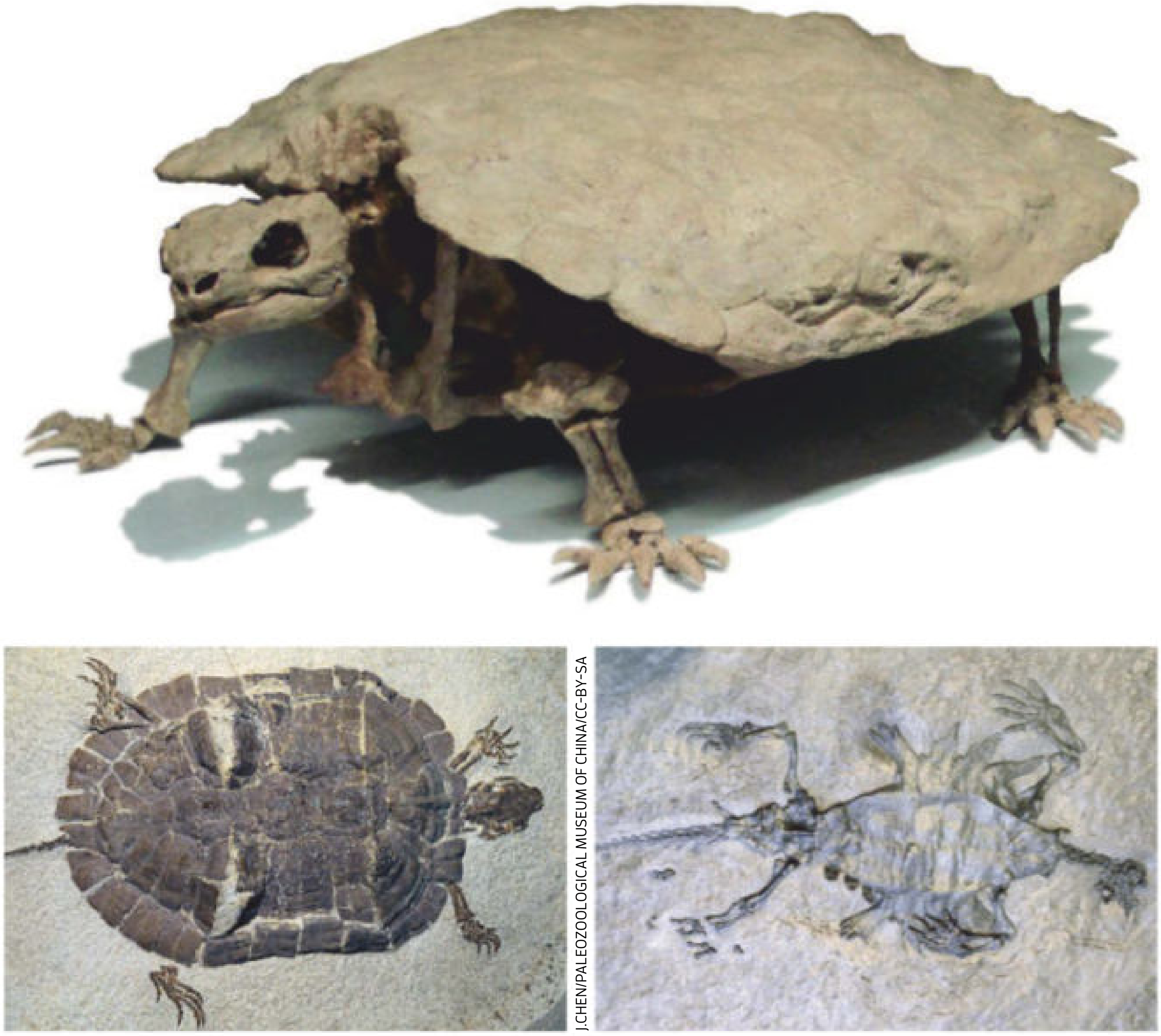
Forgotten fossil

Palaeontologists also realised that they had known about one of the most ancient turtles all along – but miscategorised it. Named in 1892, *Eunotosaurus* was thought to be a lizard from 260 million years ago that was unremarkable except for its broad ribs. But when it was compared with the newly discovered early turtles, it became clear that *Eunotosaurus* was an important part of the turtle's transformation. All these fossils add up to a reasonably clear picture of how the turtle got its shell. "The origin and early evolution of the turtle body plan has become one of the best-documented examples of an evolutionary transition in the fossil record," says Sues.

This means that we can now retell how the turtle got its shell with more confidence, just as we are also learning the truth about other famous evolutionary tricks (see "Real just-so stories", left). During the Permian period, from about 298 to 252 million years ago, lizard-like reptiles such as *Eunotosaurus* were digging into the ground for food or shelter. Those with broader ribs would have been more efficient diggers, and this conferred an advantage that was passed down.

After that, turtle ancestors evolved an abdomen shell, perhaps to protect and stabilise their internal organs from the stresses of digging. In later species, bits of bone began to form along the skin of their backs, creating a more enclosed carapace. The motions required for digging are similar to those that turtles use to swim, and so burrowing into the ground pre-adapted turtles to be competent swimmers when that evolutionary niche became available.

Fossilised turtles like *Proganochelys* (top) and the *Echmatemys* (lower left) looked much like their modern counterparts. But *Odontochelys* (lower right) only had a shell covering its bottom half



TOP: GHEDOGHEDO/CC-BY-SA

KEVIN SCHAFER/GETTY IMAGES

J.CHEN/PALEOZOOLOGICAL MUSEUM OF CHINA/CC-BY-SA

> **"Around 13 million years ago, a turtle called *Stupendemys* grew as large as a small car"**

Yet the case of turtle shell evolution isn't completely closed. In particular, there is still debate about whether the top half of the shell evolved before or after turtles began swimming. Increasingly shelled-in turtles would have had protection from attack while suspended in the water, but it is unclear whether that was a reason they took to a life aquatic or rather a downstream effect of that move.

Part of the reason we don't have firm answers here is that there are tens of millions of years between *Eunotosaurus*, *Odontochelys*, and *Proganochelys*, and we don't know what came in between. We also know little about the role of extinction events. *Eunotosaurus* and its early turtle relatives lived about 10 million years before the worst mass extinction of all time. Yet we have only the wispiest grasp of how and why turtles survived such cataclysmic times.

Researchers will undoubtedly dig out more undiscovered turtle ancestors in the years ahead. And now these discoveries won't enter an evolutionary information vacuum. Each newly discovered shell fossil is a time capsule that builds on a story we have already begun to read. ■

Riley Black is a writer based in Salt Lake City, Utah. Her most recent book is *Skeleton Keys* (Penguin Random House)

Features Cover story

Here. There. Everywhere?

Our best mathematical model of consciousness might imply everything has got it. How seriously should we take that, asks **Michael Brooks**

THEY call it the "unreasonable effectiveness of mathematics". Physicist Eugene Wigner coined the phrase in the 1960s to encapsulate the curious fact that merely by manipulating numbers we can describe and predict all manner of natural phenomena with astonishing clarity, from the movements of planets and the strange behaviour of fundamental particles to the consequences of a collision between two black holes billions of light years away. Now, some are wondering if maths can succeed where all else has failed, unravelling whatever it is that allows us to contemplate the laws of nature in the first place.

It is a big ask. The question of how matter gives rise to felt experience is one of the most vexing problems we know of. And sure enough, the first fleshed-out mathematical model of consciousness has generated huge debate about whether it can tell us anything sensible. But as mathematicians work to hone and extend their tools for peering deep inside ourselves, they are confronting some eye-popping conclusions.

Not least, what they are uncovering seems to suggest that if we are to achieve a precise description of consciousness, we may have to ditch our intuitions and accept that all kinds of inanimate matter could be conscious – maybe even the universe as a whole. "This could be the beginning of a scientific revolution," says Johannes Kleiner, a mathematician at the Munich Centre for Mathematical Philosophy in Germany.

If so, it has been a long time coming. Philosophers have pondered the nature of consciousness for a couple of thousand years, largely to no avail. Then, half a century ago, biologists got involved. They have discovered correlations between the activity of brain cells and individual instances of experience, known as qualia. But the harsh truth is that neuroscience has brought us no closer to answering the question of how neurons give rise to joy or anger, or to the smell of coffee.

This is what philosopher David Chalmers termed the "hard problem" of consciousness. Its unique difficulty stems from the inherently subjective nature of felt experience . Whatever it is, it isn't something you can prod and measure. One philosopher called consciousness the "ghost in the machine", and some people think we may never exorcise it.

DARREN HOPES

But, as Wigner pointed out, maths has a track record with hard problems. That is down to its ability to translate concepts into formal, logical statements that can draw out insights that wouldn't be exposed from just talking about things in messy human language. "This might help us to quantify experiences like the smell of coffee in ways that we can't if we rely on plain English," says Kleiner.

This is why he and Sean Tull, a mathematician at the University of Oxford, have begun formalising the mathematics behind the first and arguably only theory of consciousness with a halfway-thought-through mathematical underpinning (see "Models of experience", page 44). Integrated information theory, or IIT, was conceived more than a decade ago by Giulio Tononi, a neuroscientist at the University of Wisconsin. His basic idea was that a system's consciousness arises from the way information moves between its subsystems.

One way to think of these subsystems is as islands, each with their own population of neurons. The islands are connected by

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traffic flows of information. For consciousness to appear, Tononi argued, this information flow must be complex enough to make the islands interdependent. Changing the flow of information from one island should affect the state and output of another. In principle, this lets you put a number on the degree of consciousness: you could quantify it by measuring how much an island's output relies on information flowing from other islands. This gives a sense of how well a system integrates information, a value called "phi".

If there is no dependence on a traffic flow between the islands, phi is zero and there is no consciousness. But if strangling or cutting off the connection makes a difference to the amount of information it integrates and outputs, then the phi of that group is above zero. The higher the phi, the more consciousness a system will display.

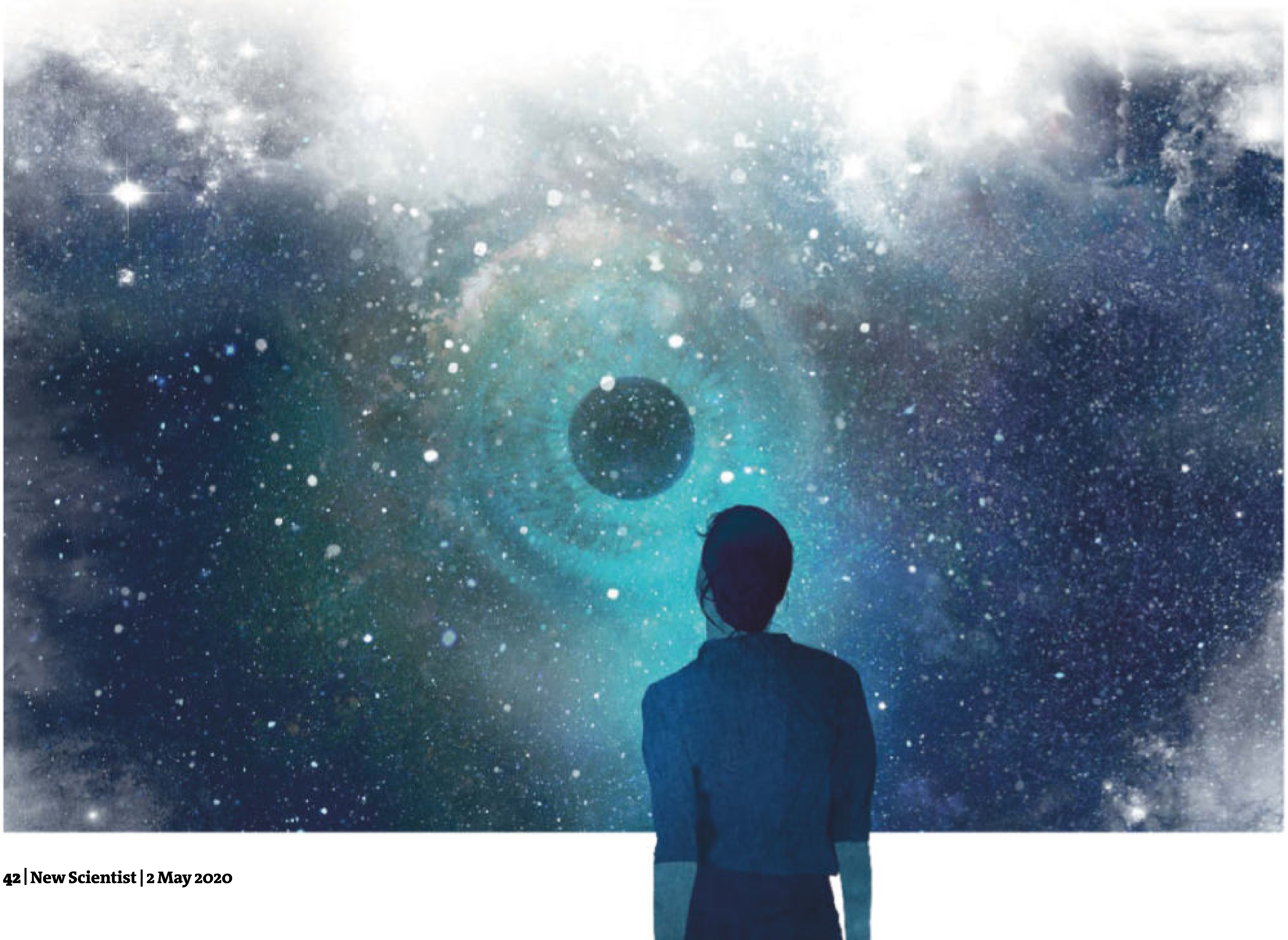
Another key feature of IIT, known as the exclusion postulate, says that a group will explicitly display consciousness only when its phi is "maximal". That is to say, its own degree of consciousness has to be bigger than the degree of consciousness you can ascribe to any of its individual parts, and simultaneously bigger than the degree of consciousness of any system of which it is a part. Any and all parts of the human brain might have a micro-consciousness, for example. But when one part has an increase in consciousness, such as when a person is brought out of anaesthesia, the micro-consciousnesses are lost. In IIT, only the system with the largest phi displays the consciousness we register as experience.

The idea has won adherents since Tononi first proposed it. "Theoretically, it's quite appealing," says Daniel Bor at the University of Cambridge. "We have this association between consciousness and intelligence: creatures able to recognise themselves in the mirror also seem to be the most intelligent. So some connection between consciousness and intelligence seems reasonable." And intelligence has a link to gathering and processing information. "That means you may as well make the related connection that in some way consciousness is related to information processing and integration," Bor says.

> **"In principle, this mathematical approach lets you put a number on a system's degree of consciousness"**

It also seems to make sense given some of what we know about consciousness in the human brain. It is compromised, for example, if there is damage to the cerebral cortex. This region has a relatively small number of highly interconnected neurons, and would have a large phi in IIT. The cerebellum, on the other hand, has a much higher number of neurons, but they are relatively unconnected. IIT would predict that damage to the cerebellum might have little effect on conscious experience, which is exactly what studies show.

IIT is less convincing when it comes to some details, though. Phi should decrease when you



Can pure mathematics describe subjective experience?

EDUARD MUZHEVSKYI/SCIENCE PHOTO LIBRARY

go to sleep or are sedated via a general anaesthetic, for instance, but work in Bor's lab has shown that it doesn't. "It either goes up or stays the same," he says. And explaining why information flow gives rise to an experience such as the smell of coffee is problematic. IIT frames conscious experience as the result of "conceptual structures" that are shaped by the arrangement of parts of the relevant network, but many find the explanation convoluted and unsatisfying.

Philosopher John Searle is one of IIT's detractors. He has argued that it ignores the question of why and how consciousness arises in favour of making the questionable assumption that it is simply a by-product of the existence of information. For that reason, he says, IIT "does not seem to be a serious scientific proposal".

Perhaps the most troubling critiques of IIT as a mathematical theory concern a lack of clarity about the underlying numbers. When it comes to actually calculating a value for phi for the entirety of a system as complex as a brain, IIT gives a recipe that is almost impossible to follow – something even Tononi admits.

"As it's currently given, phi is very difficult to calculate for a whole brain," Tull says. That might be a bit of an understatement. Researchers have worked out that using the current method, calculating phi for the 86 billion neurons of the human brain would take longer than the age of the universe. Bor has worked out that just calculating it for the 302-neuron brain of a nematode worm would take 5×10^{79} years on a standard PC.

And when you calculate phi for things you wouldn't expect to be conscious, you get all sorts of strange results. Scott Aaronson, a theoretical physicist at the University of Texas at Austin, for example, was initially excited by the theory, which he describes as "a serious, honourable attempt" to figure out how to get common sense answers to the question of which physical systems are conscious. But then he set to testing it.

Aaronson took the principles of IIT and used them to compute phi for a mathematical object called a Vandermonde matrix. This is a grid of numbers whose values are interrelated, and can be used to build a grid-like circuit, known as a Reed-Solomon decoding circuit, to correct errors in the information that is read off CDs and DVDs. What he found was that a sufficiently large Reed-Solomon circuit would have an enormous phi. Scaled to a large enough size, one of these circuits would end up being far more conscious than a human.

The same problem exists in other arrangements of information processing routines, Aaronson pointed out: you can have integrated information, with a high phi value, that doesn't lead to anything we would recognise as consciousness. He concluded that IIT "unavoidably predicts vast amounts of consciousness in physical systems that no sane person would regard as particularly 'conscious' at all".

Aaronson walked away, but not everyone sees highly conscious grid-shaped circuits as a deal-breaker. For Kleiner, it is simply a consequence of the nature of the beast: we lack information because any analysis of consciousness relies on self-reporting and intuition. "We can't get reports from grids," he says. "This is the problem."

Rather than abandoning a promising model, he thinks we need to clarify and simplify the mathematics underlying it. That is why he and Tull set about trying to identify the necessary mathematical ingredients of IIT, splitting them into three parts. First is the set of physical systems that encode the information. Next is the various manifestations or "spaces" of conscious experience. Finally, there are basic building blocks that relate these two: the "repertoires" of cause and effect.

In February, they posted a preprint paper demonstrating how these ingredients can be joined in a way that provides a logically consistent way of applying the IIT algorithm for finding phi. "Now the fundamental idea is well-defined enough to make the technical problems go away," says Kleiner.

Their aspiration is that mathematicians will now be able to create improved models of consciousness based on the premises of IIT – or, even better, competitor theories. "We would be glad to contribute to the further development of IIT, but we also hope to help improve and unite various existing models," Kleiner says. "Eventually, we may come to propose new ones."

One consequence of this stimulus might be a reckoning for the notion, raised by IIT's application to grid-shaped circuits, that inanimate matter can be conscious. Such a claim is typically dismissed out of hand, because it appears to be tantamount to "panpsychism", a philosophical viewpoint that suggests consciousness is a fundamental property of all matter. But what if there is something in it?

> **"Particles or other basic entities might have simple forms of consciousness that combine to make our own"**

To be clear, no one is saying that fundamental particles have feelings. But panpsychists do argue that they may have some semblance of consciousness, however fragmentary, that could combine to generate the various levels of consciousness experienced by birds or chimpanzees or us. "Particles or other basic physical entities might have simple forms of consciousness that are fundamental, but complex human and

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animal consciousness would be constituted by or emergent from this," says Hedda Hassel Mørch at Inland Norway University of Applied Sciences in Elverum.

The idea that electrons could have some form of consciousness might be hard to swallow, but panpsychists argue that it provides the only plausible approach to solving the hard problem. They reason that, rather than trying to account for consciousness in terms of non-conscious elements, we should instead ask how rudimentary forms of consciousness might come together to give rise to the complex experiences we have.

With that in mind, Mørch thinks IIT is at least a good place to start. Its general approach, analysing our first-person perspective in terms of what we perceive when certain brain regions become active and using that to develop constraints on what its physical correlate could be, is "probably correct", she says. And although IIT as currently formulated doesn't strictly say everything is conscious – because consciousness arises in networks rather than individual components – it is entirely possible that a refined version could. "I think that the core ideas underlying IIT are fully compatible with panpsychism," says Kleiner.

That might also fit in with indications from elsewhere that the relationship between our consciousness and the universe might not be as straightforward as we imagine. Take the quantum measurement problem. Quantum theory, our description of the basic interactions of matter, says that before we measure a quantum object, it can have many different values, encapsulated in a mathematical entity called the wave function. So what collapses the many possibilities into something definite and "real"? One viewpoint is that our consciousness does it, which would mean we live in what physicist John Wheeler called a "participatory universe".

"The universe's consciousness might have been excluded by the evolution of our own"

There are many problems with this idea, not least the question of what did the collapsing before conscious minds evolved. A viable mathematical model of consciousness that allows for it to be a property of matter would at least provide a solution for that.

Then there's University of Oxford mathematician Roger Penrose's suggestion that our consciousness is actually "the reason the universe is here". It is based on a hunch about quantum theory's shortcomings. But if there is any substance to this idea, the framework of IIT – and its exclusion postulate in particular – suggests that information flow between the various scales of the universe's contents could create different kinds of consciousness that ebb and flow depending on what exists at any particular time. The evolution of our consciousness might have, in IIT's terms, "excluded" the consciousness of the universe.

Or perhaps not. There are good reasons to remain sceptical about the power of maths to explain consciousness, never mind the knock-on effects for our understanding of physics. We seem to be dealing with something so involved that calculations may not even be possible, according to Phil Maguire, a computer scientist at Maynooth University in Ireland. "Breaking down cognitive processes is so complex that it is not feasible," he says.

Others express related doubts as to whether maths is up to the job, even in principle. "I think mathematics can help us understand the neural basis of consciousness in the brain, and perhaps even machine consciousness, but it will inevitably leave something out: the felt inner quality of experience," says Susan Schneider, a philosopher and cognitive scientist at the University of Connecticut.

Philip Goff, a philosopher at Durham University, UK, has a similar view. Consciousness deals with physical phenomena in terms of their perceived qualities, he points out – the smell of coffee or the taste of mint, for example – which aren't conveyable in a purely quantitative objective framework. "In dealing with consciousness, we need more than the standard scientific tools of public observation and mathematics," Goff says.

But Kleiner isn't put off. He is developing a mathematical model that can incorporate ineffable, private experiences. It is currently undergoing peer review. And even if it doesn't work, he says, something else will: "I'm fully convinced that in combination with experiments and philosophy, maths can help us proceed much further in uncovering the mystery of consciousness." ▮

Michael Brooks is a *New Scientist* consultant and author of *The Quantum Astrologer's Handbook*

Models of experience

There are many models for how consciousness arises. Here are four leading ones

INTEGRATED INFORMATION
Says that consciousness arises from the way information moves between different areas of the brain, or different parts of any system (see main story). It purports to let you measure consciousness by quantifying how well the system integrates information.

GLOBAL NEURONAL WORKSPACE
States that consciousness happens when one part of the brain broadcasts to others. If the prefrontal cortex deems incoming information sufficiently important, it sends the message out to a wider network known as the "global workspace" – the stage on which experience occurs.

ATTENTION SCHEMA
Rejects the assumption that consciousness is some sort of "ghost in the machine" and instead suggests a mechanistic explanation: that it is a product of how the brain models itself paying attention, whether to the outside world or its own internal states.

PREDICTIVE PROCESSING
Treats the brain as a prediction machine, anticipating sensory inputs so that it can work as efficiently as possible. The idea holds that what we consciously experience, including our sense of self, is often based on what we expect, not what is there.

This is part two of a two-part deep dive into the...

Value of Vaccines

Read more online at www.healthawareness.co.uk

Vaccines are our best weapons against pandemics

From measles to the next unknown pandemic, medical immunisations remain an essential component to the sustainable control of infectious diseases. First, however, they must be available and accepted.

Thomas M. File, Jr., M.D., MSc, FIDSA
President, Infectious Diseases Society of America

The vaccine development era of last century ushered in the ambitious global public health era of this century. This led to the eradication of smallpox and the near eradication of polio. It enabled the elimination of measles in countries across the globe, and greatly reduced the global impacts of deadly infections such as pertussis and childhood meningitis. Even as violence and political instability have undermined efforts to gain control of the ongoing Democratic Republic of Congo Ebola outbreak, a newly developed vaccine has protected health workers, families and communities and averted even more damage.

With the inspiration of these examples, the nearly four-decade quest for a vaccine against HIV has continued. Other, proven prevention measures have also spurred strides toward ending the pandemic's global impact.That's because we know what vaccines can do. Every year, vaccines are estimated to prevent from two million to three million deaths globally. The accelerated rollout of measles vaccines between 2000 and 2017 alone led to an 80% worldwide drop in measles deaths. Still, the full value of this formidable weapon against preventable illnesses and deaths remains unrealised.

Misinformation and access barriers cost lives

In spite of the proven value of vaccines, 1,200 measles infections were recorded last year in the United States – the highest number since 1992 – despite a declaration in 2000 that local transmission of the virus had been eliminated. Failures to overcome vaccine hesitancy, inspired by misinformation campaigns, as well as obstacles to routine healthcare access has enabled the spread of preventable disease. While the great majority of illnesses in the United States were among people who had not been vaccinated, that was only part of the story.

It is important to note the outbreaks all originated with travellers who imported the disease from countries where measles remains endemic – and where vaccine access is limited. Due to obstacles, including long distances to clinics, health system supply gaps and health worker shortfalls, a 2019 WHO/CDC report found that global coverage with the first dose of measles vaccine stalled at 85%. This is significantly shy of the 95% necessary to prevent outbreaks.

Goals and resources can save lives

A new global immunisation strategy by the World Health Organization (WHO), to accelerate and expand vaccine coverage, is important and timely.

An early draft of the strategy calls for countries to develop improved methods and means to educate vaccine-hesitant families and communities – on vaccine safety and effectiveness. In the US, the VACCINES Act, under consideration by Congress, would support those efforts on the domestic front, and also strengthen surveillance and responses to outbreaks of vaccine-preventable diseases. The WHO draft strategy also calls for supporting immunisation capacities during outbreaks, as well as other emergencies including conflicts. WHO also should set global goals with deadlines for coverage of universally important vaccines, including those for measles, mumps and rubella (MMR) and for diphtheria, tetanus, and pertussis (DtaP). Those goals and deadlines can drive investment priorities, propel progress, and build accountability.

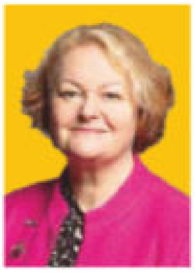
Infectious diseases don't observe borders

Implementing these strategies will require strengthened health systems in many countries lacking resources to provide the routine health care needed to detect, prevent and respond to health threats where they originate. Continued and sustained US leadership and support of global health security partnerships will be crucial to accomplishing that goal overseas, and essential to protecting health at home.

Read more at
healthawareness.co.uk

The importance of vaccines for all

As COVID-19 continues to spread, the topic of a vaccine is repeatedly raised, although it is unlikely one will be available for at least a year.



Dr Philippa Whitford
MP for Central Ayrshire and Chair, All Party Parliamentary Group on Vaccinations for All

However, World Immunisation Week (24-30 April) gives us the opportunity to reflect on the remarkable impact vaccination has already had on global society.

Immunisation is one of the most cost-effective ways to prevent deadly disease and contribute to improving the health of children across the world. This year, the UK is hosting the Global Vaccine Summit and will continue as the lead donor to Gavi, the Vaccine Alliance, which has helped save three million lives.

The role of vaccines

Vaccines are playing an increasing role in preventing cancer and other conditions, as well as fighting infectious diseases, as antibiotic resistance becomes a greater challenge. While microbes appear to be developing resistance to antibiotics more quickly, most vaccines do not lose their efficacy.

The need for comprehensive vaccination of all children

Vaccination has led to a dramatic reduction in serious infectious diseases that were once commonplace.

Smallpox was completely eradicated in 1977 through a global vaccination programme, and we are within touching distance of eradicating polio which, before the vaccine was introduced in 1956, caused up to 7,000 cases of paralytic polio and 750 deaths in the UK each year. The UK has already renewed its commitment to the Global Polio Eradication Initiative.

However, vaccine-derived cases will only be prevented by the intensive polio campaign becoming part of a more systematic approach: ensuring comprehensive vaccination of all children with the 11 key childhood vaccines recommended by the World Health Organization (WHO).

The importance of remaining above the WHO vaccination safe level

While there is a strong drive to improve vaccination rates for children in developing countries, uptake in the UK is dropping, with many vaccines falling below the 95% WHO safe level, particularly in England.

The outbreak of measles across Europe in 2019, which led to over 80,000 cases and more than 70 deaths, is testament to the importance of immunisation. Measles has come to be seen as a trivial condition in the UK, despite causing almost 150,000 deaths worldwide last year.

The spurious campaign against the measles, mumps and rubella (MMR) vaccine has left many young adults in the UK and Europe unvaccinated and led to significant, and indeed fatal, outbreaks in recent years. However, a recent report by the Royal Society of Public Health has shown that complacency, lack of access, lack of awareness, and logistical challenges are greater contributors to these falling rates than 'anti-vaccine' campaigns.

The reduction in life-threatening or disabling illnesses because of immunisation has led to complacency about the need for its ongoing use. This World Immunisation Week join us as we build the political will and support required to deliver vaccines to all, no matter where they live.

This article is sponsored by **ARTEL.**

How to ensure quality in vaccine development

The COVID-19 pandemic means that it's more important than ever to minimise sources of variability in the assay – or, quality control – process, and so lead to the design of a better, more robust product.

Dr Nathaniel Hentz
Director, Scientific Market Development, Artel

The vaccine sector is highly regulated, notes Dr Nathaniel Hentz, Director of Scientific Market Development at Artel, a company that offers products, services, and expertise to help life science labs meet their objectives for quality, productivity and compliance.

"Vaccine developers are obliged to follow regulations and established procedures," he says. "The problem is, there are guidances for how to validate an assay, but no guidance is available to tell them how to build a proper assay; yet the quality of the assay is what drives the quality of the entire manufacturing process.

"If it isn't done correctly it may mean a vaccine batch inappropriately passes or inappropriately fails. This could have a direct impact on patient safety, which is always the industry's number one concern."

Unfortunately, assays are only as good as the tools that are used to assemble them, and thus subject to different sources of variability.

"An assay is built using many components," says Dr Hentz. "Take liquid handling, for example, a series of steps that move liquids from point A to point B. This can be done with an automated system, or by scientific staff pipetting by hand. But, if pipetting techniques are different — particularly if multiple analysts are working on the same assay in different laboratories — then operator to operator inconsistency can occur."

Employing measuring tools, methods and training to minimise sources of variability

Liquid handling is just one source of variability in the assay process. Others include mixing, labware, plate-washing, time, temperature, etc.

However, measuring tools, methodologies and training are available to help labs understand and minimise all sources of variability.

"By using a process optimisation approach during assay development and validation, the entire assay process can be optimised to its fullest extent," says Dr Hentz. "This can lead to the design of a much better, more robust assay."

In the scramble to find a vaccine for COVID-19, assay optimisation and quality assurance is more important than ever.

"The increased manufacturing capacity requires more samples to be tested, which in turn increases opportunities for error and that can be a challenge for labs.

"Companies don't want vaccine batches to fail because this costs them time and money and can impact the introduction to market and adoption of vaccination. Ultimately, it all comes back to patient health and safety, which is why companies are so keen to ensure product quality throughout the manufacturing process. Now, because of COVID-19, things are moving very fast, so it is important to minimise variability and any easy-to-fix mistakes."

Artel works with labs helping them achieve assay development, liquid handling performance and operator training goals. For more information, please visit: artel.co

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Lessons learned: what the Ebola outbreak has taught us

Professor Miles Carroll
Head of Research at the National Infections Service, Public Health England

From 2013 to 2016, the Ebola virus (EBOV) spread across West Africa, killing over 11,000 people and affecting around 30,000.

Public Health England (PHE) was involved early in the West African outbreak, establishing a laboratory to support the Médecins Sans Frontières treatment centre in Guéckédou, Guinea in March 2014.

As a member of the European Mobile Laboratory – a rapid response unit made up of a network of high containment labs – 25 PHE Porton Down scientists from multiple fields were deployed to front line diagnostic labs in Guinea, Sierra Leone and Liberia over the following 24 months.

Studying survivor immunity

The large number of cases and EU funding afforded the PHE team a unique opportunity to study the immune response of both survivors and known contacts of those infected with the virus in Guinea.

This formed the most comprehensive study of EBOV survivor immunity to date, thanks to the high number of survivors involved, its three-year duration, and the analysis of both neutralising antibody and T-cell responses. The latter gives us valuable insight into how EBOV can still circulate in the bloodstream after recovery, as the virus is known to hide and then re-emerge in immune-privileged sites like the eyes and testes – the latter leading to the threat of sexual transmission.

Overcoming challenges to the study

While other studies on survivor immunology exist, only a handful look at T-cell response because of the difficulty performing assays in country and in keeping the cells viable long enough to get them out of the country; they require a -80°C setting with dry ice.

We accomplished this by employing some pragmatic approaches, such as using a WHO cooling system intended for vaccines to transport samples 600 kilometres from the remote village of Guéckédou to the capital, Conakry.

> *The large number of cases and EU funding afforded the PHE team a unique opportunity to study the immune response*

The legacy of the research

Although the full study is yet to be published, over the last three years we have been providing data to the European Medicines Agency, the US Food and Drug Administration and the WHO Vaccines Committee, to assist their regulatory review process in licensing Merck's Ervebo vaccine and other candidates still to be licensed.

Good relationships require investment and consistent communication, and when we returned each year, we shared our latest analysis with the participating survivors.

Through the leadership network, also made up of survivors, we explained what their immune responses to the virus meant in terms of protection against re-infection and different strains of EBOV.

Looking ahead to coronavirus

Professor Miles Carroll, Head of Research at the National Infections Service, PHE, says, "The dedication of the Ebola Virus Disease (EVD) Survivors' Association enabled us to carry out this analysis and collect data which has been critical to vaccine development.

"This undertaking required enormous teamwork from partners including the Guinean state, the UK Foreign and Commonwealth Office, and colleagues within PHE's National Infection Service."

"All our capabilities and resources are now being applied in the international effort to find a new vaccine against COVID-19."

Read more at healthawareness.co.uk

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Collaboration & Community: Confronting Vaccine-Preventable Diseases

The impact of COVID-19, still tragically being felt, brings to the fore the potentially devastating effects of diseases for which there is no prevention or cure. The focus now is on finding a vaccine or treatment in response to a pandemic that has been overwhelming.

It is unlikely that this will be the last new virus we see. The progress we make today, the investments we make in science, social care and strong public-private partnerships, and the value we place on prevention will be vital in helping us to respond to future crises and protect populations against diseases and their impact.

Collaboration is essential

I can't help but be inspired by the scientific collaboration across borders and the speed of innovation during this time of crisis. According to the London School of Hygiene & Tropical Medicine, there are already 119 vaccine candidates in active development across more than eight different vaccine types; 110 in pre-clinical development, eight in Phase I, and one in Phase II.* Of these, over 40% are collaborative efforts making it likely that the goal of developing a vaccine will be achieved through collective efforts. Continued cooperation with governments, fellow pharmaceutical and biotechnology companies, and international agencies to accelerate the development of these vaccine candidates and identify others is imperative. I'm immensely proud to work for a company that cares about doing the right thing and as such is working closely with organisations including Translate Bio, the Biomedical Advanced Research and Development Authority (BARDA), the Coalition for Epidemic Preparedness Innovations (CEPI), the Bill and Melinda Gates Foundation, and the European Medicines Agency (EMA). In addition, we have joined forces with GlaxoSmithKline (GSK) to pool resources and explore every opportunity to accelerate the development of a candidate vaccine.

Community comes first

The World Health Organization (WHO) recently stated that disruption to immunisation programmes during a pandemic can result in an increase in vaccine-preventable diseases (VPDs) and that such outbreaks could result in VPD-related deaths, increasing the burden on health systems already strained by the pandemic response. This situation has undoubtedly heightened awareness of the importance of disease prevention and the value of vaccination. Despite the worry and uncertainty, we must continue to show our commitment to our communities, not only by taking measures to slow the spread of the novel coronavirus but also by helping to prevent the resurgence of vaccine-preventable infectious diseases.

By HUGO FRY
Managing Director
of Sanofi UK

Looking ahead

The values of solidarity, innovation and collaboration that define our response to this pandemic must, and will, continue to underpin the work we do.

We must continue to recognise the value of vaccination to public health. The new partnerships forged in the context of the pandemic have demonstrated the essential value of collaboration and this must form the foundation of scientific progress. As a company we are calling for the establishment of the European equivalent of BARDA, which may help increase incentives for proactive vaccine research and development. Governments must also continue to invest in innovative new vaccines, guided by the evidence and recommendations of scientific bodies, and make concerted efforts to drive uptake.

Vaccines are one of the most important tools we have in our arsenal to help protect the health of people and communities worldwide. The lessons we take forward can strengthen our collective ability to do this.

> “*The goal of developing a vaccine will be achieved through collective efforts*

Sanofi is dedicated to supporting people through their health challenges. We are a global biopharmaceutical company focused on human health. We prevent illness with vaccines, provide innovative treatments to fight pain and ease suffering. We stand by the few who suffer from rare diseases and the millions with long-term chronic conditions.

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**All figures correct at time of publication*

To find out more about our work, please visit: **www.sanofi.co.uk**

What are the critical access challenges for vaccines in the US?

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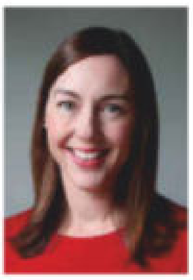
Ensuring the highest possible vaccine uptake across the population of the US requires navigating the fragmented nature of the country’s healthcare coverage and delivery system.

Richard Hughes IV
Managing Director, Avalere Health



Kelly Cappio
Associate Principal, Avalere Health

“I’ve worked in vaccines for around 15 years,” says Richard Hughes, Managing Director and the Vaccines Leader at Avalere Health, a Washington DC-based advisory firm specializing in strategy, policy, and data analysis for life sciences, health plans, and providers.

“I’ve observed many opportunities to provide better vaccine access, and the COVID-19 pandemic really underscores their value in preventing major outbreaks and why access to them is so vital.”

US vaccine access challenges

One of the challenges for ensuring equitable vaccine access in the US, explains Hughes, is the fragmented nature of the country’s healthcare coverage and delivery system.

For instance, the Affordable Care Act (ACA), passed in 2010, requires that commercial health insurers cover recommended vaccines with zero cost-sharing. This means that nearly everyone with private health insurance in the US has better vaccine access.

Seniors in the US, aged 65-plus, have access to the flu and pneomoccocal vaccines without cost sharing, under the Medicare physician benefit (Medicare Part B). However, other vaccines for seniors are covered under the Medicare drug benefit (Medicare Part D), which has variable cost-sharing levels across plans. “Absent supplemental coverage, seniors may pay an average of $50 out of pocket for vaccines under Part B,” says Hughes.

The traditional Medicaid program, which covers those with limited income and resources who are often more vulnerable to health issues, has variable vaccine coverage and cost-sharing requirements across states.

Overcoming barriers to vaccination access

“Since the ACA passed, significant headway has been made to address financial barriers to vaccination, namely coverage and cost-sharing,” says Kelly Cappio, Associate Principal at Avalere Health.

“However, many Americans still experience coverage gaps and prohibitive out-of-pocket costs. Policymakers could consider ways to achieve parity across the private and public insurance markets — including covering vaccines the same, across sites of care, and eliminating patient cost sharing.”

These challenges require sophisticated solutions to overcome them – systems to connect patients to access or ensure providers are reimbursed – or, ultimately, policy reform to resolve the fragmentation of vaccine coverage and access

Additionally, “The US ACIP’s (Advisory Committee on Immunization Practices) increasingly complex recommendations have become more challenging for payers to implement and for providers to communicate, possibly leading to missed opportunities to protect a patient” says Hughes. “ACIP recommendations could be clearer. The vaccine pipeline is robust. And with new emerging non-vaccine technologies emerging, there’s also an opportunity for the ACIP to advise on the use of novel products that effectively play the same role as a vaccine.”

How COVID-19 will change the development of vaccines

With respect to a COVID-19 vaccine, “The ACIP will likely have a crucial role to play here,” says Cappio. “Given the urgent need, a vaccine may be deployed pre-licensure under an Emergency Use Authorisation by the Food and Drug Administration (FDA).

“Typically, the ACIP doesn’t make a recommendation for use of a vaccine before it receives FDA licensure; but in extraordinary circumstances the committee is able to provide guidance on the use of unlicensed vaccines and there is a likelihood they recommend that certain subgroups, like healthcare workers, receive the vaccine first. Later, when the vaccine is available for broader use, ACIP would need to determine whether to recommend it to the wider US population.”

> “Since the ACA passed, significant headway has been made to address financial barriers to vaccination, namely coverage and cost-sharing,” says Kelly Cappio, Associate Principal at Avalere Health.

The US Congress took legislative steps in March to ensure access to future COVID-19 vaccines, requiring the vaccine to be covered under the Medicare physician benefit with zero cost-sharing and providing enhanced federal funding for state Medicaid programs that cover the vaccines at first dollar. Should the ACIP recommend the vaccine for use, commercial plans will also be required to cover it.

Hughes expects the COVID-19 crisis to have a long-lasting impact on vaccine development. “More broadly, this pandemic is likely to shape the long-term healthcare and public health outlook in many ways for good. If there’s any silver lining at all, it’s that.”

Written by:
Tony Greenway

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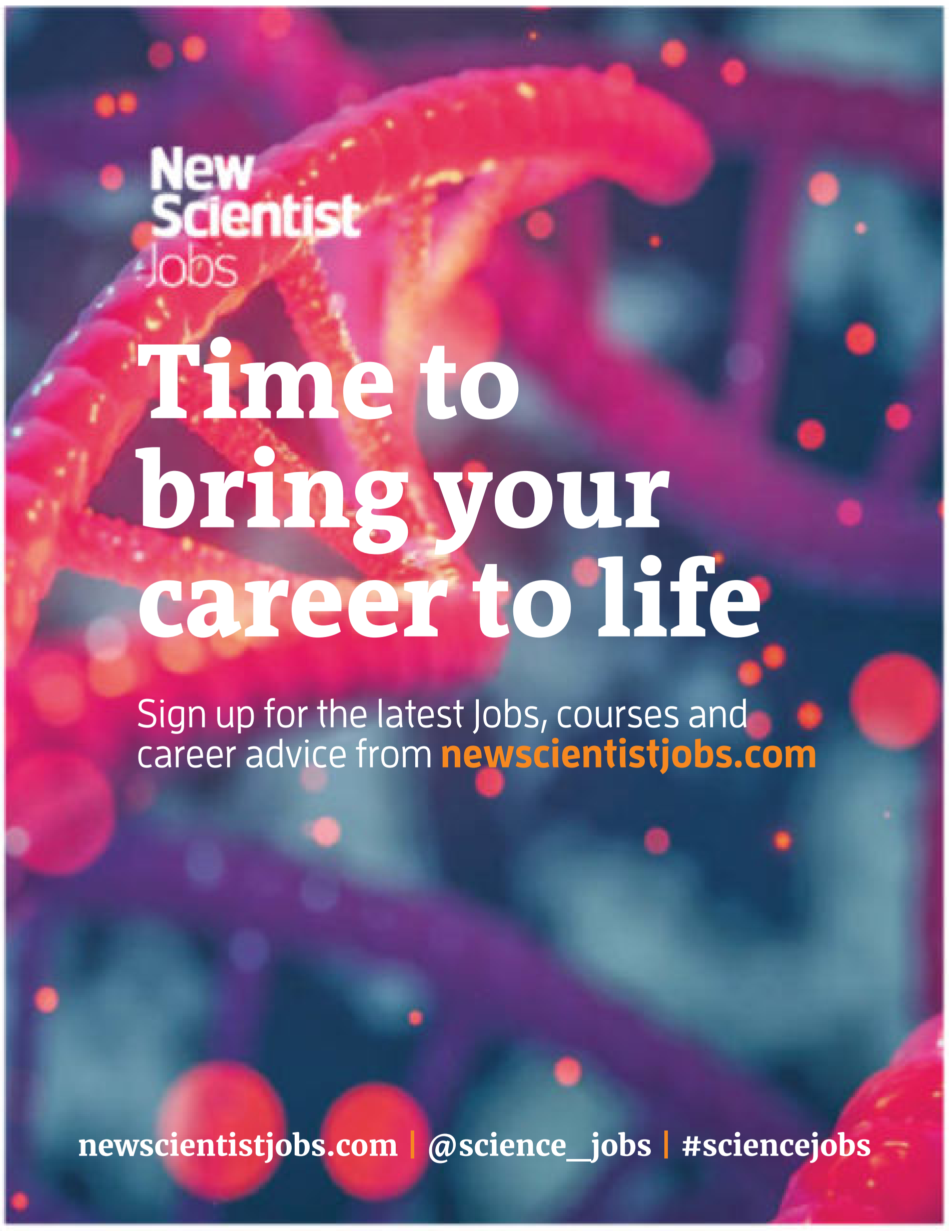

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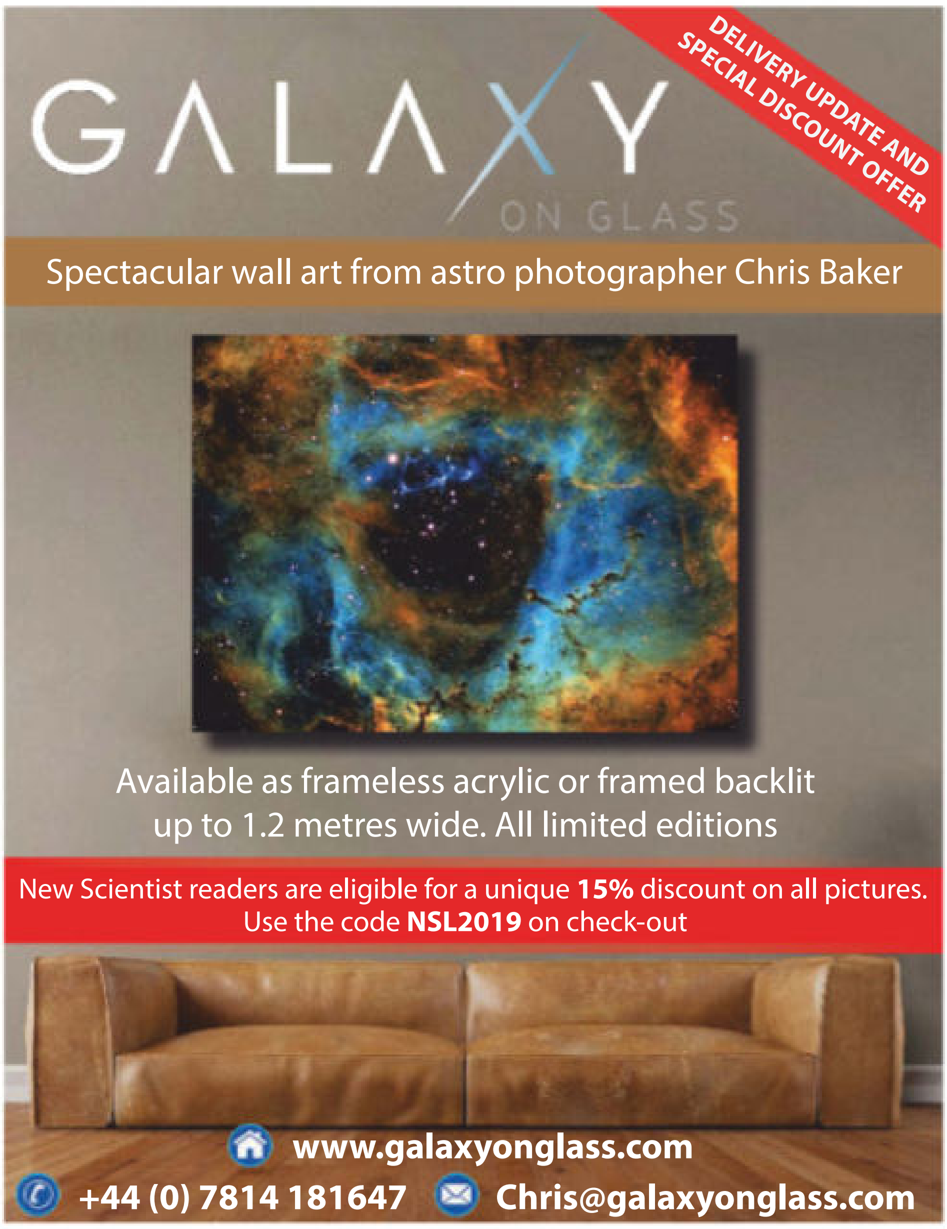

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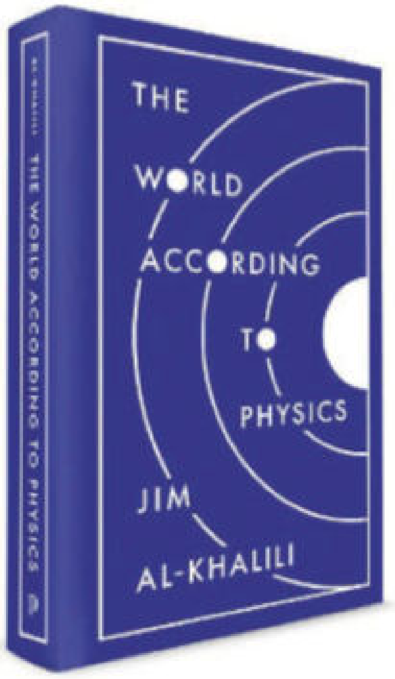

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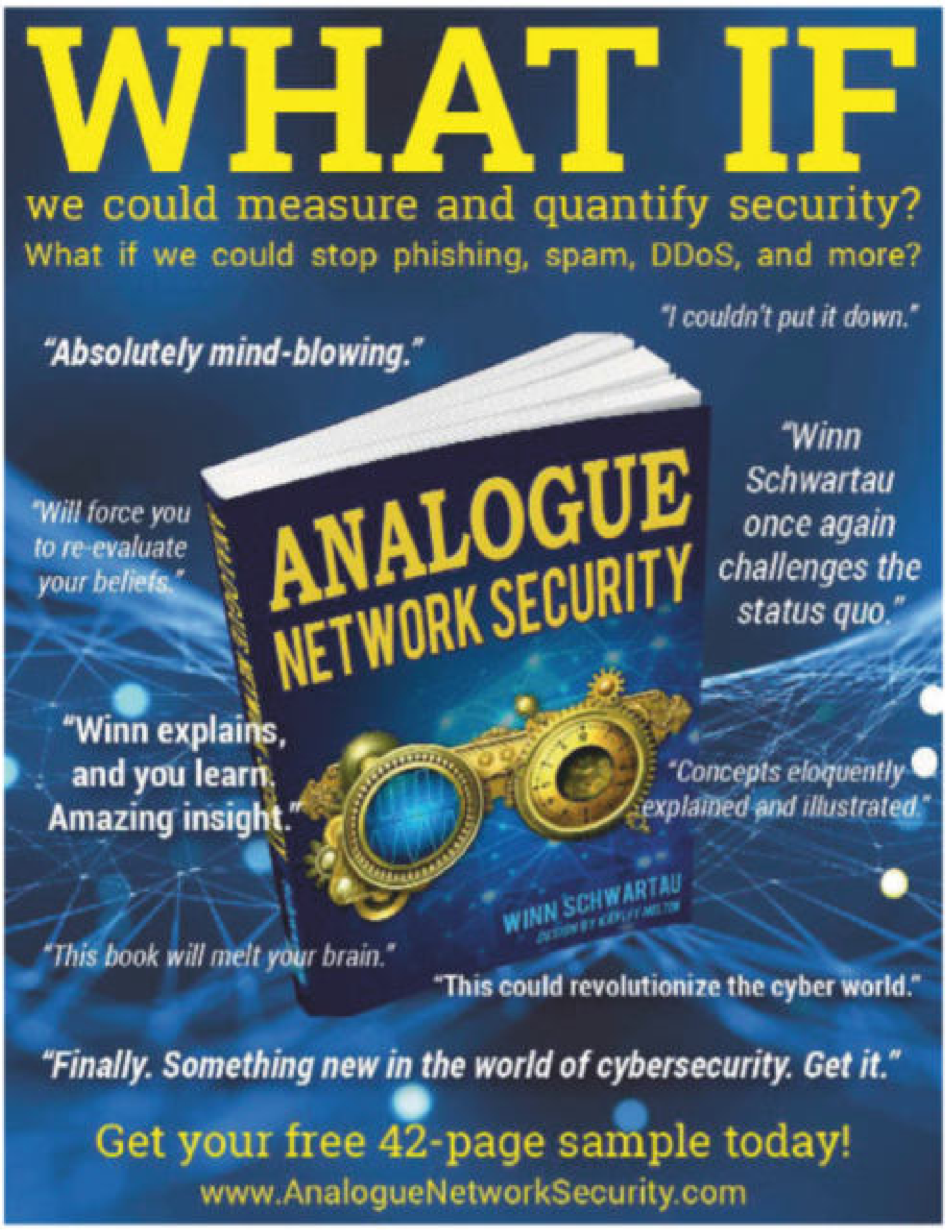

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***Almost* the last word**
How are monuments aligned with the sun? Readers respond p54

The Q&A
Alice Gorman tells why she treasures the debris in space p56

Science of cooking **Week 18**

Turn up the heat

Getting your wok scorching hot and preparing your ingredients in advance is the best way to make a tasty stir-fry, says **Sam Wong**

Sam Wong is social media editor at *New Scientist*. Follow him @samwong1

What you need

Vegetables of your choosing
Meat (optional)

STIR-FRYING sounds like a simple way to cook food, but it is so easy to do it badly. Each ingredient should be cooked to the point of being done and no more. Meat is browned on the outside, but still tender. Vegetables retain a fresh flavour and crunchy texture, but their exteriors have developed that slightly smoky flavour that comes from high heat, without any parts being burnt.

Cantonese chefs call the flavour imparted by stir-frying in a wok "*wok hei*". This means wok energy or, more poetically, wok breath. The exact source of *wok hei* is a matter of debate. Some of it no doubt comes from Maillard reactions, when sugars and amino acids react at high temperatures.

Some chefs say that *wok hei* comes from the combustion of oil, particularly when food is tossed into the air over a flame and small droplets of oil ignite. Smoke from the wok may also contribute.

True *wok hei* comes from skilled chefs expertly marshalling the heat on professional burners that get much hotter than domestic hobs can. A recent study by researchers at Georgia Institute of Technology looked into the mechanics of wok tossing techniques used by professional chefs to make fried rice.

The chefs employed a see-saw motion, using the stove rim as a fulcrum, to toss the rice into the air and catch it in the wok. They consistently tossed at a frequency of 2.7 cycles per second, a rate determined by the time it takes for the rice to jump up to 20 centimetres into the air and fall back into the wok. This fast rate keeps the food moving constantly, allowing it to char in the high heat without any burning.

This technique is difficult to emulate at home, but you can still make a good stir-fry without powerful restaurant burners.

First, use a wok. Its high sides create lots of cooking surface and help you to keep food moving constantly without it escaping.

Chop your ingredients into evenly sized pieces that will cook quickly. Have everything prepared before you start cooking, so you don't have to go looking for something midway through.

Turn up the heat as high as you can. Preheat the wok with nothing in it. Don't be afraid if it gets smoky. Extractor fans and windows are your friends.

Once the wok is hot, add oil just before adding other foods, so it doesn't decompose on the high heat. Use a flavourless oil like vegetable oil or peanut oil, which can reach high temperatures without breaking down.

Keep food moving constantly to ensure that it cooks evenly without burning. Don't put too much food into the wok, or it will cool down too much. If you need to, cook in batches, then combine everything at the end. ▮

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Science of cooking online
All projects are posted at
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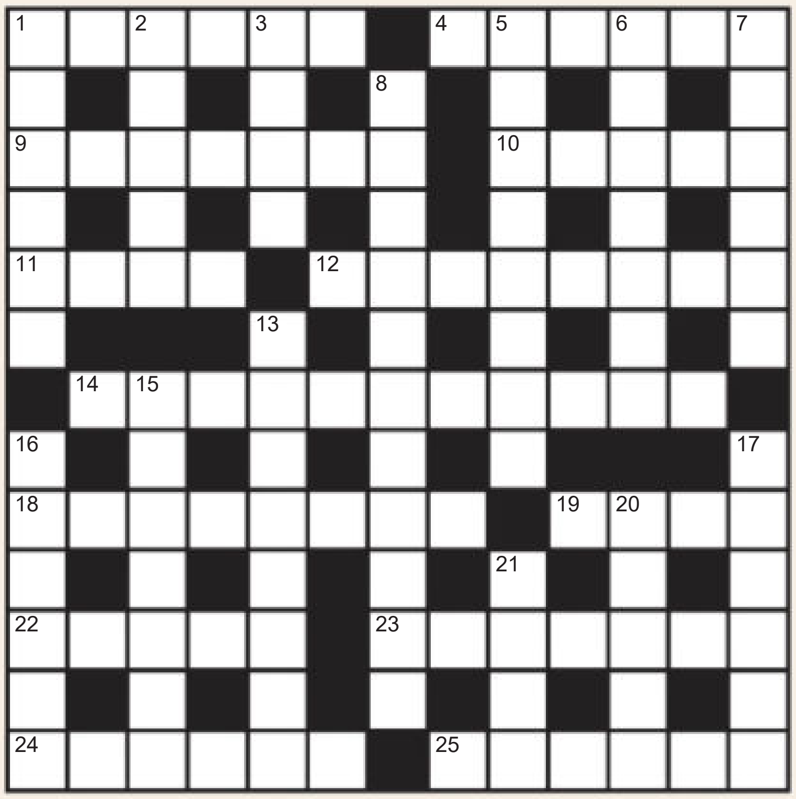
Cryptic crossword #30 *Set by Wingding*



ACROSS

1 Extract of garlic and lemon that might be found on a restaurant table (6)
4 Result of each flap felt everywhere? Chaos theory's origins (6)
9 Blood clots in Amy's heart interrupting pulse: the onset of illness (7)
10 Leaf buds comprising oxygen, copper and lithium (5)
11 Surgical procedure out of proportion in public (4)
12 Urinate audibly with vigour, showing sign of illness (8)
14 Mr Li's science experiment (not new) making shapes (11)
18 8 down may be kept here, in messy bed with Craig (8)
19 A fish that bacteria might grow on (4)
22 Harass graduate with accepted theory (5)
23 Desire alcohol in five-year period (7)
24 Put under watch, getting around incomplete information (6)
25 Some salami a smartly rejected cause of disease? (6)

DOWN

1 German goes into outskirts of Copenhagen for fabric (6)
2 Natural leader sure to be irritated in 5 8's job (5)
3 Note carried by politician could be enlightening (4)
5 God informally enclosed by wall in European city (8)
6 Learned to make EU editor unwell with hypoxia (7)
7 Get air circulating and assess casualties (6)
8 Singer we hear bestowing honour on porter, perhaps (11)
13 Diagram showing Spooner's bit of tea (3,5)
15 Violently angered! (7)
16 Accepts elevation of *Australopithecus* species (6)
17 Illegal action on a site of conflict (6)
20 Country without any source of sickness or causes of disease (5)
21 Drink piece of plastic (4)

Answers and the next quick crossword next week.

Quick quiz #49

1 What precious metal, with atomic number 78 and a name derived from the Spanish for "little silver", are you likely to find in a car's catalytic converter?

2 What does the endocrine system do?

3 How many rooms does Hilbert's Grand Hotel have?

4 Dorothy Hodgkin won the 1964 Nobel prize in chemistry for pioneering work using what technique to elucidate biomolecular structures?

5 Some of Hodgkin's most influential work involved which product of the islets of Langerhans?

Answers below

Quick Crossword #56
Answers

ACROSS **9** Acoustic horizon, **10** Dry cell, **12** Oceanic, **13** Edible fig, **15** Taste, **16** Postfix, **18** Osmosis, **21** Eider, **24** Ammeter, **25** Blogger, **28** Lunar coordinate

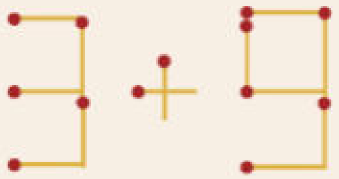
DOWN **1** Sand, **2** Bony, **3/23/16D/5** A smell of petroleum prevails throughout, **4** Gill, **6** Arrest, **7** Ozonises, **8** Unscrews, **11** Radio, **14** Fox sparrow, **17** Sediment, **19** *Myosotis*, **20** In use, **22** Rotors, **25** Bark, **26** Gram, **27** Rhea

Quick quiz #49
Answers

1 Platinum
2 Produce and regulate hormones within the body
3 An infinite number. David Hilbert invented the hotel to expose apparent mathematical paradoxes in accommodating infinite guests
4 X-ray crystallography
5 Insulin; the islets of Langerhans contain the pancreas's insulin-making cells

Puzzle *set by Paulo Ferro*

#57 Matchstick magic



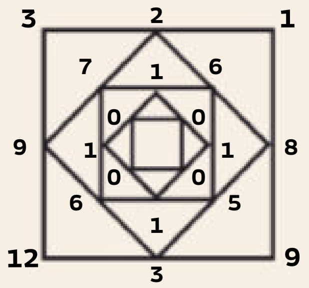
Your challenge is to move two matchsticks to produce a calculation that gives an odd number. How many solutions can you find?

1-3: well done. 4-6: brilliant.
7-10: amazing. 11: exceptional.

Answer next week

#56 Diffy

While the numbers 1, 3, 9 and 12 give you five Diffy squares (shown below), placing 1, 3, 6, and12 clockwise around the square will give you 10 Diffy squares. You can find them by a combination of working backwards and some experimentation. For example, since the final square has 0, 0, 0, 0 at its corners, the one before it must be c, c, c, c (where c is some whole number). To get beyond that, some more trial and error is needed.



Numbers that create a high number of Diffy squares are related to what is known as the tribonacci sequence: 1, 1, 2, 4, 7, 13, 24... Each term is the sum of the previous three (the name is a pun on the more famous Fibonacci sequence in which you add the previous two numbers). Note that the four tribonacci numbers 2, 4, 7, 13 are one higher than our solution 1, 3, 6, 12.

Our crosswords are now solvable online
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Turtly awesome

In these lockdown days when all but essential travel is forbidden, Feedback has been fascinated to discover what people in other parts of the world consider essential.

Topping the charts, in our view, is the Italian woman who was fined 400 euros by police in Rome for taking her turtle (tortoise for UK readers) for a walk. It turns out that exercising your live-in chelonian – even if it is just for a 3-hour stroll round the block – doesn't qualify as essential in covid-hit Italy.

What also piqued Feedback's interest was news organisation Agence France Presse's decision to refer to the turtle as "pizza-sized". How big is this pizza, we asked our colleagues. Presumably, one replied, turtle-sized.

An aptly circular argument, but not one that takes us very far. Unless, to coin a phrase, it is stuffed-crust turtles all the way down – hell for logicians but paradise for teenage mutant ninjas.

We've cracked it

Scientific terminology, like a good can of air freshener, can make even the most distasteful subjects presentable. Embarrassed to talk about your watery bowel movements? Identify instead as being a type 7 on the Bristol stool scale. Your colleagues don't want to hear stories of parasitic wasps whose larva eat their way out of the living bodies of hosts? Refer to the life cycle of *Ichneumon eumerus* instead and your audience will be rapt.

A co-worker forwarded a particularly good example to Feedback this week, a study taken from a presumably much pored-over medical journal called *JAMA Dermatology*.

Entitled "Onabotulinum Toxin A for Sacral and Intergluteal Cleft Hyperhidrosis", our colleague points out a more accurate summary of its findings would have been that botox injections stop excessive sweating from the butt crack. Doesn't have quite the same ring to it, now does it?

If you have spotted any particularly amusing uses of scientific jargon recently, feel free to direct them hither via the medium of electronic mail.

Super savers

The island of Singapore was widely hailed for its swift response to the coronavirus crisis. It is hardly surprising that – even now, several months into the global pandemic – the city state is continuing to innovate in its response.

Just the other day, its government released illustrations of five new coronavirus-themed superheroes to be used in official literature.

They are: Dr Disinfector, Circuit Breaker, Fake News Buster (who carries a Mallet of Truth that gives Feedback a serious case of prop-envy), Must Always Walk Alone Man (who – and this isn't a word of a lie – detests Liverpool Football Club and its chant of "You'll Never Walk Alone"), and Care-leh Dee (pronounced Care Lady, like some sort of patronising women-only soap range).

If only the UK was willing to do something similar. We can see them now, striding purposefully over the horizon in skin-tight Lycra: Lift The Lockdown Man, But I Want To Go To The Park Kid, Captain Behavioural Science and their fearless commander It's Just Like The Flu Lady.

Sadly, the coronavirus-fighting superheroes of Singapore have been withdrawn after falling foul of a force even they couldn't defeat: the ire of Liverpool football fans.

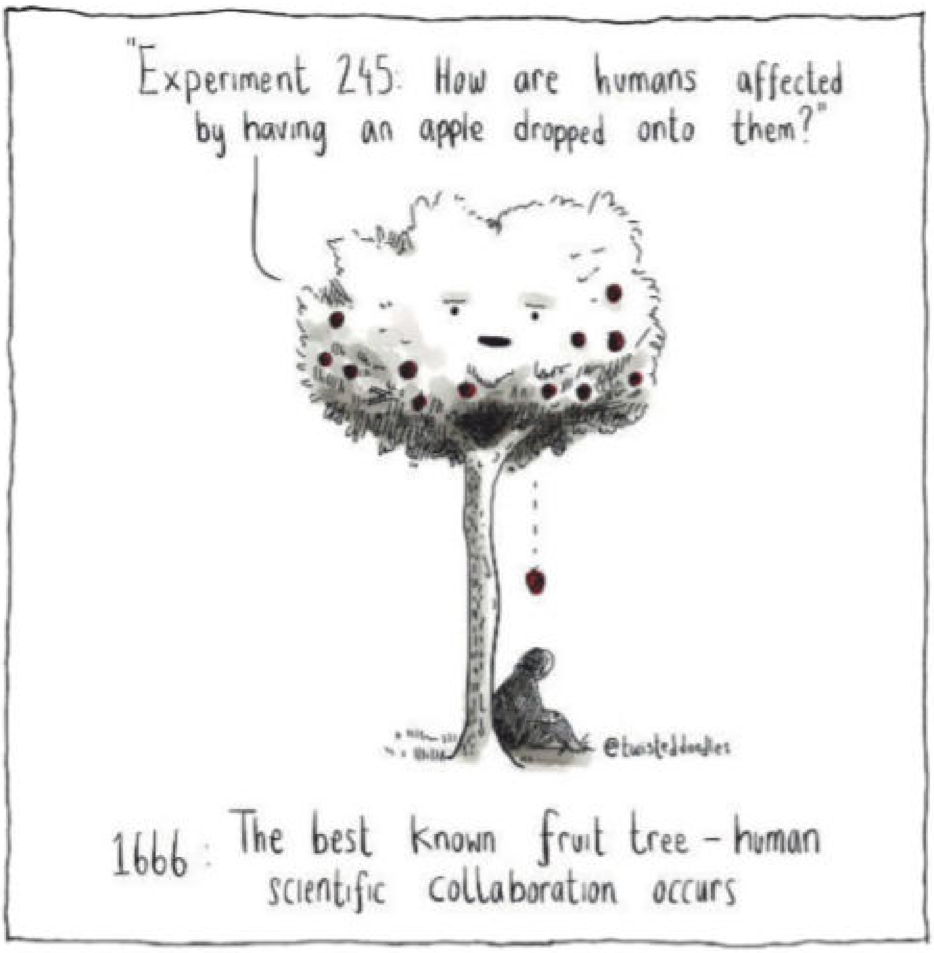
Ghosting

Singapore isn't alone in taking innovative measures to combat the virus. Nearby Indonesia is also getting in on the act, enlisting the undead to help fight for the living. Or, at least, sort of.

According to the BBC, Kepuh village on the island of Java has drafted volunteers to sit on public benches after dark and pretend to be ghosts. In the photo that accompanies the article, two sorry looking men sit at either end of a bench, swathed in white and looking for all the world like a pair of undrawn curtains.

We applaud the village's creativity – and the villagers' sense of civic duty – but if you aren't scared of a global pandemic then what impact is someone dressed as a roll of toilet paper really likely to have? Now, somebody dressed as a shortage of toilet paper – that is scary.

Twisteddoodles *for New Scientist*


"Experiment 245: How are humans affected by having an apple dropped onto them?"
@twisteddoodles
1666: The best known fruit tree – human scientific collaboration occurs

Stop starter

The only thing Feedback loves more than pointless technology is the smartwatch app we have developed to track how many times we've mentioned pointless technology in our column. As an aside, we have also programmed a smart bulb over our heads to turn purple every time we make a meta-joke, so we are enjoying its aubergine glow right now.

This week's addition to the list is a doozy, though. Sourd.io, as an article in *The Verge* reports, "is like a fitness tracker for your sourdough starter".

A device designed to fit in the lid of your average sourdough starter container, it can measure the temperature, humidity and volumetric increase of your bread-making microbial baby. One thing it can't do, though, is track when your nearest and dearest are sick and tired of you wanging on about sourdough starters. Shame – that could have actually been useful.

Well would you look at that, there goes the purple light bulb again.

Got a story for Feedback?

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Mysterious alignment

How can ancient monoliths that were aligned with the sun at the equinox thousands of years ago still be lined up, given that plate tectonics moves land masses over the years?

Mike Follows
Sutton Coldfield, West Midlands, UK
This is because tectonic plates move very slowly. As a rule of thumb, they move at about 40 millimetres a year, the speed at which fingernails grow.

The Great Pyramid of Giza was built in around 2560 BC, so roughly 4500 years ago. Yet it is out of alignment with true north by less than one-fifteenth of a degree. Giza sits at the north-east corner of the African tectonic plate, which has moved 30 metres north and spun anticlockwise by about one-sixtieth of a degree since the Great Pyramid was built, when its alignment with true north was even closer.

If the African plate had moved eastwards at a typical speed of 40 millimetres a year, or around 180 metres over four-and-a-half millennia, the effect of this spin would have been negated. A similar argument can be made for the alignment of ancient monoliths with the sun at equinox.

Geoff Townson
Charmouth, Dorset, UK
The Eurasian tectonic plate is moving east at approximately 25 millimetres a year. However, because the direction of movement is more or less along an imaginary line linking sunrise and sunset, there has been little lateral shift in the alignment of ancient European monoliths in relation to equinox since they were built. If the plate's drift was from north to south, then there would have been a noticeable offset.

Chris Daniel
Colwyn Bay, Conwy, UK
The question about the effect of plate tectonics on stone circle alignment is something that I have sometimes wondered about too.

Many prehistoric stone circles and other structures in the UK and Ireland date back 5000 years or more. Some are thought to have been built to align with the equinoxes and solstices.

The British Isles are on the western side of the Eurasian plate. The tectonic movement in this region has been measured at about 25 millimetres a year in a northerly direction. So, in the past 5000 years, the land has drifted about 125 metres north, or about one-thousandth of a degree of latitude.

At Stonehenge, for example, this change has barely altered the position of the sun as it rises on midsummer morning. The angle between the sun as it appears on the horizon and due south – the azimuth – has decreased by about one-thousandth of a degree, a practically imperceptible amount.

The effect of tectonic movement is, however, dwarfed by that caused by the change in Earth's axial tilt, called the obliquity of the ecliptic. This angle is currently a little less than 23.5 degrees, but 5000 years ago, it was closer to 24 degrees. This change alone has increased the azimuth of sunrise at Stonehenge on midsummer morning by more than one degree, an amount equal to two diameters of the sun on the horizon.

At Stonehenge, a marker stone called the Heel Stone isn't precisely aligned with midsummer sunrise, leading some scholars to believe that it must have been in the correct position when the prehistoric monument was built, believed to be in about 3000 BC.

In reading around this subject, I came across a letter in *New Scientist* from 18 November 1976, in which the writer, V. J. Phillips, calculated the amount of tectonic drift since Stonehenge was built, although from a different time direction than I did, at one third of a mile.

MODE IMAGES/ALAMY

Could shaking a kettle help it to heat up water quicker?

This week's new questions

Power nap **Why do some people generate useful ideas while asleep? Does the subconscious mind have a trick up its sleeve?** ***Adrian Chong**, Melbourne, Australia*

Slow boil **Does a kettle boil quicker if you shake it? It certainly sounds different.** ***Alan Phillips**, Carterton, New Zealand*

Great fleas

How small does an animal or insect have to be before it can't have fleas, mites or lice?

Roy Harrison
Verwood, Dorset, UK
There is an answer to this question attributed to UK mathematician Augustus De Morgan, who is known to computer programmers as the inventor of computational rules known as De Morgan's laws.

Great fleas have little fleas upon
their backs to bite 'em,
And little fleas have lesser fleas,
and so ad infinitum.
And the great fleas themselves,
in turn, have greater fleas to go on;
While these again have greater still,
and greater still, and so on.

Roger Lord
Brisbane, Australia
The question immediately bought to mind a verse attributed to Ogden Nash:

Little bugs have littler bugs,
Upon their backs to bite 'em
And littler bugs have littler bugs,
And on ad infinitum.

Fleas are highly specific to their hosts and field studies have been conducted to address this question for several small mammals. These include the field vole (*Microtus agrestis*), which is between 8 and 13 centimetres long and weighs 14 or 15 grams, and the common shrew (*Sorex araneus*). At 5 to 8 centimetres in length and 5 to 12 grams in weight, this is probably the smallest animal reported to have fleas.

Jonathan Swift's version of the verse appears to predate both Nash's and De Morgan's – Ed.

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We have sent plenty of things into space over the years. To **Alice Gorman** these objects aren't mere detritus, but precious artefacts to be studied while we still have the chance

So, what do you do?

I'm a space archaeologist. I study the artefacts and sites that are evidence of human engagement with outer space. I'm interested in how humans use objects to adapt to different space environments, whether that's through orbital robots or Velcro, which was popularised after it was used in NASA space missions.

What is space archaeology?

I use archaeological methods and theories to investigate the culture of space exploration. It's about how space technology changes through time, and how it reflects social and scientific beliefs. While history focuses on the documents, archaeology looks at the material objects.

What kinds of artefacts are there to study?

We have left orbiters, landers, rovers and probes on many celestial bodies in the solar system. Earth orbit is full of junk, like the Vanguard 1 satellite, which was launched in 1958 and is the oldest human object in space. The moon has over 60 landing sites, including the only ones where humans have ever been off-world.

How did you end up working in this field?

I used to be a regular archaeologist. I worked as a heritage consultant with Aboriginal communities in Australia, specialising in stone tools. Once, I was looking up at the night sky and I had a revelation: the space junk orbiting Earth is our heritage too.

What are you working on right now?

I'm looking at the archaeology of the International Space Station with my fellow space archaeologist Justin Walsh at Chapman University in California. We are using machine learning to analyse millions of NASA images to show how crew members interact with objects over time.

How has your field of study changed since you started working in it?

When I started out as a space archaeologist, there is no doubt that many of my colleagues thought it was a little cracked. Over the past decade we have made space archaeology a recognised field. And there is now some urgency about it. Even five years ago, all the heritage sites on the moon were more or less safe from disturbance. Now, everyone wants to go back to the moon and damage to these sites is no longer a theoretical concern.

Were you good at science at school?

I loved science, and I'm not ashamed to say I read encyclopaedias and textbooks for fun! I did well in all the sciences except physics, which I passed but didn't shine in. It was enough to make me feel that a career in astrophysics was off the table. Boys could be average, but girls had to be brilliant to break into these fields back then.

If you could have a conversation with any scientist, living or dead, who would it be?

I'd love to meet Emilie du Châtelet. She translated Isaac Newton's *Principia Mathematica* into French and in her commentary reconceptualised the relationship between energy, mass and velocity. Voltaire was her lover and they worked together on experiments. However, I'd argue that she was more brilliant than Voltaire, as she helped him during the day as well as managing the household and her family, and had to work on her own research at night.

> "One night I looked up at the sky and had a revelation: space junk orbiting Earth is our heritage too"

Do you have an unexpected hobby, and if so, please will you tell us about it?

I like inventing space cocktails! My favourite creation is the Spider from Mars (in Australia, ice-cream sodas are called spiders): crème de cassis, freeze-dried ice cream, Prosecco and a green jelly baby as a garnish.

How useful will your skills be after the apocalypse?

As an archaeologist, I'm someone you will want to keep around. I know how to choose the right stone to make stone tools, plus a myriad of other ancient technologies that will keep us alive.

OK, one last thing: tell us something that will blow our minds...

There's an empty experimental space station in orbit, Genesis II – but it's not quite empty. It was sent into space with a population of Madagascar hissing cockroaches.

Alice Gorman is based at Flinders University in Adelaide, Australia. She is the author of *Dr Space Junk vs The Universe* and tweets as @drspacejunk

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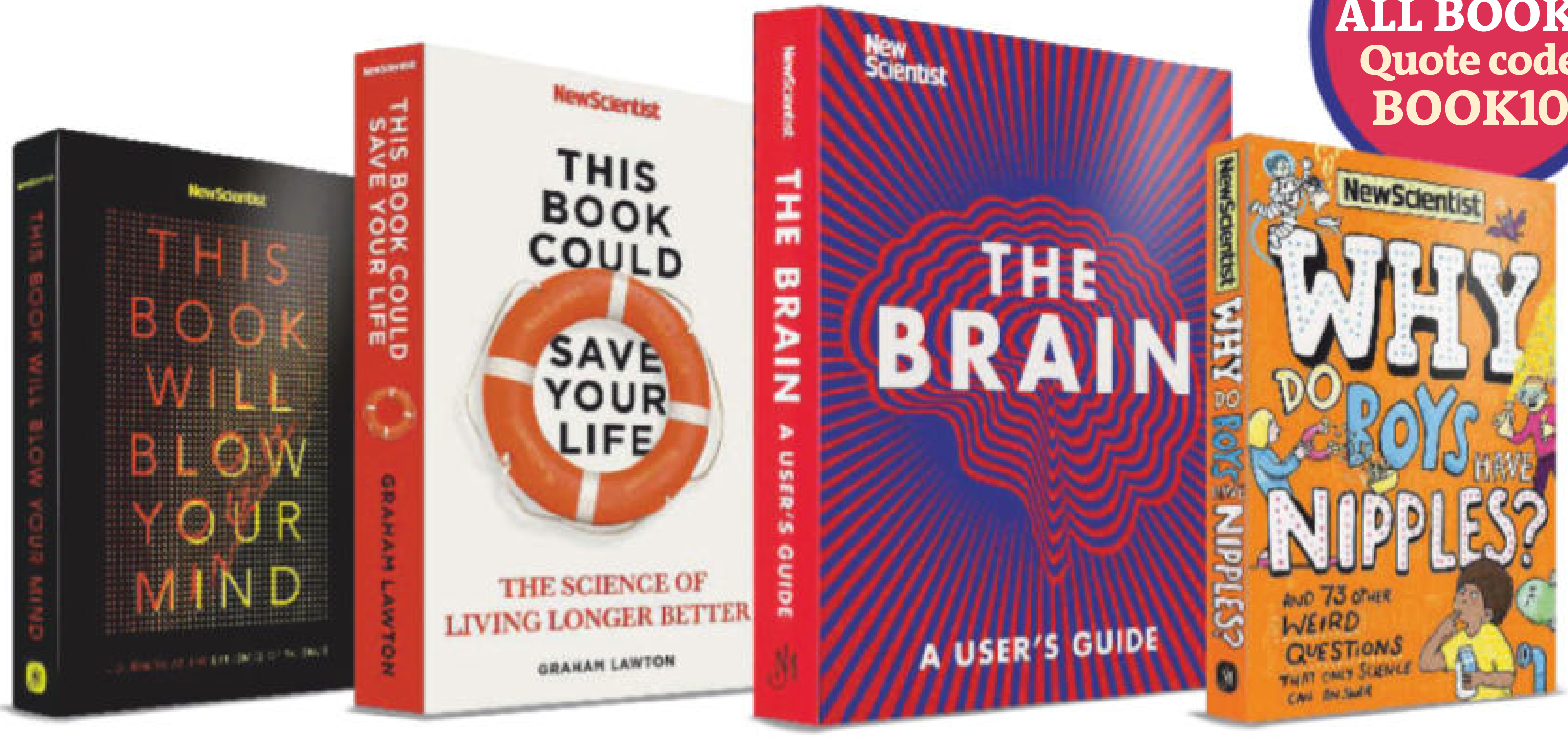
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